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AN
INTRODUCTION TO ZOOLOGY

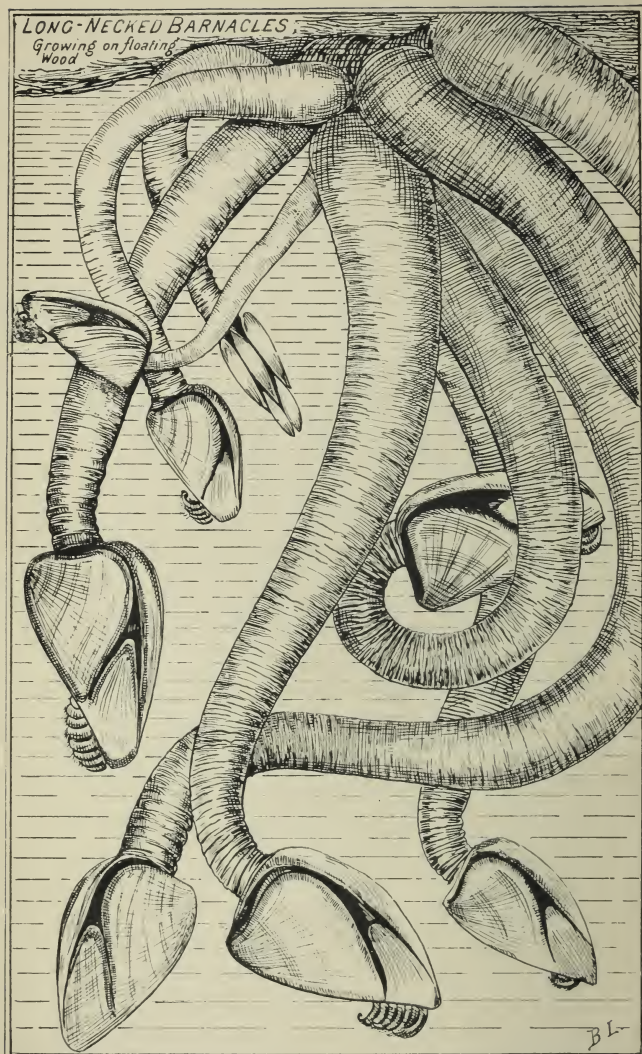


FIG. 51.—THE LONG-NECKED BARNACLE (*Lepas anatifera*). See p. 187.

AN INTRODUCTION
TO THE STUDY OF
ZOOLOGY

BY

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WITH 124 ILLUSTRATIONS AND DIAGRAMS



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PREFACE.



THIS little book is a kind of guide-book for readers who are about to begin the study of Zoology. It aims at supplying a simple outline sketch of the animal kingdom, so as to enable the reader to map in, as it were, his own particular field of study in its right place in the general scheme of zoological knowledge. It is also intended to guide the reader to the use of standard works. A story has been told of a working man who saved up money enough to buy an expensive work on natural history, and of his disappointment, when he found that much of it was obsolete and the whole of it old-fashioned. It is to prevent disappointments of this sort that this little book is intended. I have given a list of text-books and other literature of the subject, which, though far from exhaustive, practically includes everything that can be useful to the readers for whom I have written, and very likely a great deal more.

In compiling the book, I have had lively recollections of my own experiences in preparing for the Cambridge Higher Local Examination more than a

decade ago, hampered by obsolete text-books and general want of information ; but I have not intended it primarily for scholastic uses. I have had in view, as I have already hinted, the large and, I trust, increasing class of adult students who want a first lesson-book in a given science, which treats that subject from its very first elements, and yet treats it in a manner not calculated to draw down upon the volume and its author the remonstrance brought by Dickens's bricklayer against Mrs. Pardiggle's tract, that "*It's a book fit for a babby, and I'm not a babby.*" The commercial man, the clerk, and the well-educated artisan help to make up the class of students I refer to—students whose enthusiasm for knowledge is such as to lead them to seek it, self-taught and self-guided, in their short intervals of leisure.

Many of these isolated and self-taught students of Zoology have both means, leisure, and intelligence sufficient to enable them to carry on their studies to some purpose, but are wasting their time over obsolete books and worthless microscope slides, for want of a guide to the whereabouts of knowledge. This want I have endeavoured in some degree to supply.

B. L.

ERRATA.

- Page 61, line 7—*For* "homologous" *read* "homogeneous."
- „ 67, „ 12—*Transpose the words* "in all but the simplest animals" *to end of line 15.*
- „ 74, „ 3—*For* "animals develop" *read* "animals which develop."
- „ 88, „ 2—*For* "appreciation" *read* "understanding."
- „ 118, „ 22—*For* "Molluscoidea" *read* "Molluscoida."
- „ 133, „ 29—*For* "Chætopoda" *read* "Chætopoda."
- „ 174, „ 14—*For* "those" *read* "the nerves."
- „ 180, „ 14—*For* "Fig. 46" *read* "Cf. Fig. 46."
- „ 186, „ 2, 4—*For* "Arthropoids" *read* "Arthropods."
- „ 182, „ 1—*Omit the word* "some."
- „ 299, „ 16—*For* "Fig. 12" *read* "Fig. 121."
- „ 321, „ 30—*For* "earning" *read* "learning."
- „ 322, „ 28—*For* "Horsell" *read* "Hornell."
- „ 332, „ 13—*For* "Horsell" *read* "Hornell."

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A number of the cuts used in this volume have been taken from Claus and Sedgwick's *Text-book of Zoology*, by the kind permission of the editor, while several cuts relating to botanical subjects have been taken from Prantl and Vines' *Text-book of Botany*. Many of the others, from various standard works, have been kindly supplied by the publishers of Cassell's *Popular Natural History* and of Pokorný's *Naturgeschichte des Thierreichs*; Figs. 1, 5, 7, 8, 9, 10, 11, 12, 13, 20, 21, 23, 24, 35, 44, 45, 51, and 133 were drawn for the present volume.

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GLOSSARY.

Alimentary Canal.—The digestive tube through which food passes ; a simple tube in the simpler animals, but differentiated into several regions in the higher ones. The stomach region is regarded as its middle part, and is therefore sometimes spoken of as the mid-gut, while the gullet region and the intestinal region are distinguished respectively as the fore-gut and hind-gut.

Alternation of Generations.—Some animals and plants have two different forms, the one of which is developed in an asexual manner from the other, while this in its turn is developed sexually from the former. This cycle of alternating development is called alternation of generations. See p. 150.

Amœbiform (like an *Amœba*).—A term applied to a cell capable of changing its shape by pushing out pseudopodia and then retracting them, as *Amœba* does. This is the primitive form of the animal cell. (*Amœba*, from Gk. ἀμείβω, to change ; formerly called the *Proteus* animalcule, from Proteus, the Greek divinity, who possessed the power of changing his shape.)

Analogous (Gk. ἀναλογία, analogy), comparable.—An organ in one kind of animal is said to be *analogous* with an organ in another kind of animal when it fulfils the same uses. Thus the breathing-tubes (tracheæ) of an insect are the analogue of the lungs of a mammal ; they fulfil the same purpose, although derived from a wholly different part of the body.

Anatomy (Gk. ἀνά and τομή, cutting up).—The art of dissecting ; hence, the study of the parts of the body. Comparative anatomy, the study of the way the parts of the body vary in different animals, sometimes called morphology.

Animalcule, pl. **Animalcules** (Lat. *animalculum*, pl. *animalcula*, diminutive of *animal*).—A name formerly given to the unicellular organisms, and others too small to be seen without a microscope.

Appendage.—This general term is applied to the many different forms of legs and feelers borne by articulated animals. It is useful, as implying that they are all modifications of one general type ; namely, that of a body-ring bearing a pair of movable organs, which may be jaws, antennæ, legs, gills, etc.

Archenteron (Gk. ἀρχε- first, and ἔντερον, see ENTERON).—The primi-

tive body-cavity of embryo animals; believed to represent the fact that their ancestors belonged to that low stage of animal structure found in the *Cœlenterata*, where the body-cavity and stomach are identical.

Azygous (Gk. *áz*, without, and *ζυγόν*, yoke, cross-bar joining two sides).—Unpaired; a term applied to structures in the middle of the body. Really they are composed of two halves, so it is much better to refer to them as *median* structures.

Biology (Gk. *βίος*, life, and *λόγος*).—The study of living bodies, including both plants and animals.

Blastoderm (Gk. *βλάστος*, germ, and *δέρμα*, skin).—The developing germ or embryo of animals that have eggs containing yolk; so called because it lies flat on the top of the yolk, like a thin skin.

Budding.—The asexual formation of a new animal by a simple process of growth from the body of the old one. The outgrowth, when it has developed the various parts of a new animal, breaks off from the other. Colonial animals are formed by repetitions of this process.

Cæcum, pl. **Cæca** (Lat. *cæcus*, blind).—A bag-like branch of any cavity; *i.e.* a sac with what we call metaphorically a *blind* end, just as we speak of a *blind* street, meaning one with no outlet. Cæca are attached to the alimentary canal in many animals; when they occur in invertebrates there are usually several of them; but in the higher vertebrates there is only one.

Cell.—See **PLASTID**.

Cloaca (Lat. a sewer).—This name is applied to the common passage which serves for the ejection of both excretory and generative products in some animals, *e.g.* birds and reptiles.

Cœlom or **Body-Cavity** (Gk. *κοῖλος*, hollow).—In nearly all animals the internal organs are contained in a common cavity: this is called the cœlom or body-cavity. See p. 40.

Cœnosarc (Gk. *κοινός*, shared in common, and *σάρξ*, flesh).—The tissue which unites the unit organisms of a colonial animal. In many kinds it becomes hard, and forms a sort of stalk on which they seem to be borne, *e.g.* corals.

Condyle (Gk. *κόνδυλος*, knuckle).—The *joint* (occipital condyle, from Lat. *occiput*, the head) by which the skull is set on to the spinal column; double in amphibia and mammalia, single in reptiles and birds (*Sauropsida*).

Differentiation (Lat. *differentia*, difference).—The gradual establishment of different parts in the course of growth.

Distal (Lat., from *disto*, to be distant). At the far end: thus the hand is at the *distal* end of the arm.

Diverticulum (Lat., a way turning off in another direction). A passage or chamber branching off from the main portion of any cavity.

Ectoderm (Gk. *ἐκτός*, outside, and *δέρμα*, skin).—The name given to the outside layer of the body in those comparatively simple

animals in which the primary body-layers can still be obviously distinguished in the adult; *e.g.* hydra, jelly-fish. In the higher animals they are so folded and complicated that this is difficult.

Egg.—The name given to the structure in which the young of many animals are inclosed. An egg contains the germ, *i.e.* *ovum*, or egg-cell, with food-yolk to supply it with nourishment during growth, and a protective covering. In the hen's egg this last consists of albumen (white of egg) supplemented by a hard shell; in some fishes' eggs the "shell" is leathery. The egg-cell or ovum is sometimes shortly referred to as the egg.

Endoderm (Gk. *ἐνδον*, within, and *δέρμα*, skin).—The name given to the inside layer of the body when the outside is called ectoderm.

Endoplast (Gk. *ἐνδον*, within, and *πλάστος*, what has been formed or moulded, *i.e.* a shape).—Literally, a structure or shape seen inside an organism. An old name for the nucleus, still met with in descriptions of certain unicellular organisms.

Enteron (Gk. *έντερον*, in plural the intestines).—The digestive cavity of the *Cœlenterata*, which is not differentiated into body-cavity and alimentary canal.

Epiblast (Gk. *ἐπί*, upon, *i.e.* at the top of, and *βλάστος*, germ).—The outer of the three "germinal layers," from which the skin and the nervous system and sensory organs are developed.

Evolution (Lat. *evolutio*, unrolling, *e.g.* of a scroll).—The gradual *unfolding* or *opening out* of something previously hidden, packed away in small compass; hence, especially, the process of gradual growth by which the more complex types of living beings are believed to have originated from the more simple ones.

Germinal Layers.—The embryo or germ, *e.g.* of a chick, is formed of three layers, called the germinal layers. See p. 30.

Histology (Gk. *ιστός*, from *ίστημι*, to set up—the upright beam of a loom, hence the warp that was fixed to it, and the whole web; and *λόγος*).—The study of the *tissues* of living bodies (see *TISSUE*).

Homologous (Gk. *ὁμός*, like, and *λόγος*), agreeing with.—Organs derived from the same part of the body are said to be homologous with one another, although they may be quite different in appearance and in use. Example: the lungs of air-breathing vertebrates are the homologue of the swim-bladder of the fish, each being originally a cavity branching from the inside of the throat.

Hypoblast (Gk. *ὑπό*, under, and *βλάστος*, germ).—The lower, or inner of the three "germinal layers," from which is derived the glandular lining of the alimentary canal and of its appended glands.

Individual.—In the case of colonial or compound organisms, such as those occurring among the *Cœlenterata*, it is usual to speak of the whole stock of the colony, including all the different units that have been produced by budding, as one "individual." The

"individual" is thus regarded as including all the parts or buds developed from one sexually fertilized germ, although some of these buds may form apparently independent animals.

Karyokinesis (Gk. *κάρυον*, a nut, *i.e.* nucleus of a cell, and *κίνησις*, movement).—A name which has been given to the cycle of changes which the nucleus of a cell goes through before its division. See p. 21.

Larva (Lat. *larva*, a mask).—The early stage of an animal that undergoes metamorphosis: so called, because the perfect form sometimes emerges from the dried skin of the early stage, which hides it like a mask; *e.g.* the butterfly from the dried skin of the chrysalis.

Life-History.—A complete description of the different stages of any organism, from its earliest unicellular stage to its adult form, is called its life-history. The life-history of an animal presenting "alternation of generations," or of an animal which passes through metamorphosis, is of course a long story, and it is in these cases chiefly that this picturesque term is applied.

Median Line (Lat. *medianus*, situated in the middle, *medius*).—The name given to the middle line of the body in animals that are bilaterally symmetrical.

Membrane Bone.—This term is applied to bones which are derived originally from transformed scales. See p. 261. They are sometimes called **PAROSTEAL** bones (Gk. *παρά*, along-side of, and *ὀστέον*, bone), because they are applied on the outside of the true bone.

Mesenchyme (Gk. *μέσος*, middle, and *χεῦμα*, liquid).—A name given to the middle layer of the body in the *Cœlenterata*. The name refers to its jelly-like texture, which is exemplified in the *jelly-fishes*, where it is enormously developed, and has been given in order to allow for the doubt whether the middle layer of the body in these animals is derived from the primary layers in quite the same way as what is called mesoblast in the higher animals such as vertebrates.

Mesentery (Gk. *μέσος*, middle, and *έντερα*, intestines).—1. The thin, membrane-like structures by which the intestines of vertebrates are slung in their places. 2. The internal radial projections of the body-wall in sea-anemones and corals.

Mesoblast (Gk. *μέσος*, middle, and *βλάστος*, germ).—The middle of the three germinal layers, from which are derived the supporting tissues of the body (muscles and connective tissue), and also the blood.

Metamere (Gk. *μετά*, after, and *μέρος*, a part).—One of the successive similar joints of an articulated animal, such as a lobster. A "segment."

Metamorphosis (Gk. *μετά*, and *μορφή*, form).—Change of form; when an animal passes through a larval stage before it arrives

at its adult state, it is said to undergo metamorphosis. Insects afford the most familiar example, but many other animals undergo similar changes.

Morphology (Gk. *μορφή*, form, and *λόγος*).—The study of the *form* of animals. We study their form in order to draw conclusions as to their relationships with one another, which are then expressed by means of classification. It is merely a more new fashioned name for comparative anatomy (see ANATOMY); but its use is closely associated with modern ideas regarding the inter-relationship of different kinds of animals.

MORPHOLOGICAL EQUIVALENT, *i.e.* homologue; see HOMOLOGUE.

The term morphology is also applied to the study of the form of plants (Vegetable Morphology).

Notochord (Gk. *νῶτος*, back, and *χορδή*, a string).—The round string of tissue lying down the back of embryo vertebrates, underneath (ventrally to) the spinal cord. This structure, homologous with the UROCHORD of larval Ascidians, and with a similar dorsal structure in *Balanoglossus*, is one of the proofs that the vertebrates are descended from invertebrate ancestors.

Nuclear Division.—See KARYOKINESIS.

Nucleolus (diminutive of *nucleus*).—A small mass of firmer stuff inside the nucleus of a cell, which is seen in some cells, especially in those that are preparing for very active growth.

Nucleus (Lat. *nucleus*, kernel, from *nux*, a nut).—The dark body which is seen in the protoplasm of a cell. It takes up staining more readily than the rest of the protoplasm, and is therefore believed to consist of firmer material.

Ontogeny (Gk. *ὄντ-*, at present existing, hence in the singular a being or individual; and *γενεά*, birth).—The history of the development of the *individual*, from the egg-cell onwards. The “ontogenetic development” of any form of animal is spoken of in contradistinction to its “phylogenetic development.”

Organism (Gk. *ὄργανον*, an engine).—The machinery of a living creature, by means of which its life is carried on. The machinery remains when the life is gone, and a dead creature may still be spoken of as an “organism.” The simplest form of life machinery is that of a single cell, and one cell only may compose an “organism.”

Oviparous (Lat. *ovum*, an egg, and *pario*, to bring forth).—Producing the young from eggs. Examples: hen, frog, butterfly, snail.

Phylogeny (Gk. *φύλον*, a kind or race, and *γενεά*, birth).—The process of development by which any form of animal has been developed, through progressive types, from its ancestral form. The way in which the terms ontogeny and phylogeny are used can be best explained by an example: the ontogenetic development of a frog means its development from a tadpole to a frog; but the phylogenetic development of the frog means its gradual evolution from a fish-like ancestor, until it reached a stage in which the adult

form is an air-breathing animal. Thus while the stages of ontogenetic development can be seen with the eye, the stages of phylogenetic development (which, see p. 59, the former are believed to represent) can only be seen with the mind's eye.

Phylum, pl. **phyla** (Gk. *φῦλον*, a kind or race).—A name given by some zoologists to the chief sub-divisions of the animal kingdom; its use has superseded that of the older term sub-kingdom. It is a very useful and correct term, because it reminds the student that similarity of structure is understood to be due to kinship in race.

Plastid (Gk. *πλάστος*, what has been formed or moulded or shaped).—The unit of form. Both plants and animals are seen under the microscope to consist of numberless little units of structure, all much alike. Each is essentially composed of protoplasm, with a thicker part near the middle, which is called the nucleus. These units were named cells, because in the case of plant tissues there is a hollow wall left where the units are cut through and the juice runs out of them. But in animal "cells" this is not the case, therefore the name "cell" is inapplicable. The name plastid, which may be roughly rendered as "unit of form," has been therefore proposed instead.

Polyp (Gk. *πολύπος*, or *πολύπους*, many-footed).—The name applied to the units of colonial animals, from the fact that they usually possess numerous *tentacles*, "arms" or "feet"; e.g. corals. (In classical writers the name usually refers, however, to the cuttle-fish, the tentacles of which may be called feet.)

Protoplasm (Gk. *πρῶτος*, first, and *πλάσμα*, form, i.e. formative substance, from *πλάσσω*, to mould).—Primitive basis of the body; the soft, jelly-like material of the cells of living bodies, sometimes spoken of as the "physical basis of life."

Proximal (Lat. *proximus*, nearest).—At the *near* end, i.e. the fixed end; thus the shoulder is the *proximal* end of the arm.

Pseudopodium (Gk. *ψευδής*, false, *πούς*, foot).—A "false foot," temporarily pushed out by the protoplasm of a cell, and presently retracted by the contraction of the protoplasm.

Retrograde Development.—When the larval or early stages of an animal have traces of higher organization than that of the adult stage, it is concluded that the animal is descended from a higher type, and has lost some of its organs, and become degraded. It is then said to be a case of retrograde development.

Sac (Lat. *saccus*, a bag).—Any bag-like structure.

Sarcode (Gk. *σάρξ*, flesh).—Flesh-like substance; the protoplasm of minute organisms.

Segment (Lat. *segmentum*, a slice; from *seco*, to cut).—1. One of the successive similar joints of an articulated animal, such as a lobster. 2. One of the apparently similar parts into which the developing egg-cell divides itself.

Segmentation.—The process of division by which a developing egg-

cell (germ) grows. It divides into two, then each of the new parts divides again into two, and so on.

Somite (Gk. *σῶμα*, body).—A term applied to the successive parts, segments, or metameres, of a segmented animal, because each of these parts usually bears appendages, and thus affords a distinction of body and limb.

Spore Formation.—Sometimes the nucleus and protoplasm of a cell, instead of dividing into two in the ordinary way, divide into several parts lying in the middle of the cell, so that the outside layer of the old cell is left unchanged, until it is destroyed by the activity of the new cells, which burst it and make their way out. This is called "spore formation," or "endogenous cell-formation." It occurs in the reproduction of some of the Protozoa (pp. 129, 136, 140).

Syncytium (Gk. *σύν*, together, and *κύτος*, a hollow vessel, *i.e.* cell).—A colony of cells intimately united with one another by means of amœbiform processes. This has been shown to be the case with the cells which form the "segments" of the developing egg-cell.

Tissue (French, from Lat. *textus*, woven, a thing woven).—The web or substance of animal bodies, made up, not of threads, but of cells (*plastids*).

Unicellular.—Consisting of one cell (*plastid*). This is not the case in the adult stage with animals not belonging to the Protozoa; but each animal starts at first from one cell only, by the division of which the body is gradually formed.

Viviparous (Lat. *vivus*, alive, and *pario*, to bring forth).—Producing live young. The majority of animals produce their young from eggs; the Mammalia are the only animals that are viviparous as a group, and by the necessity of their structure. Occasional species among many groups of animals bring forth their young alive; but in these exceptional cases there is little special adaptation of structure for the purpose. They may be looked upon as cases in which the eggs or larvæ are delayed within the body of the parent until ready for independent existence, and are described by the term *ovo-viviparous*.

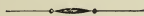
Zoology (Gk. *ζῷον*, animal, and *λόγος*).—The study of animal life, especially its study from the point of view of systematic classification.

PART I.

GENERAL PRINCIPLES OF ZOOLOGY.

AN INTRODUCTION TO ZOOLOGY.

PART I.



CHAPTER I.

THE DISTINCTION BETWEEN ANIMALS AND PLANTS.

How are animals distinguished from plants? is the first inquiry that suggests itself, when we begin to study Zoology systematically. Plants also have life, as well as animals: what is the difference between them? At first sight it seems as if this question were one that could be very easily answered. Animals move about, plants are fixed. Animals require to breathe fresh air, from which they abstract the oxygen, giving out again in return carbonic acid gas, while plants absorb carbonic acid gas, and give out oxygen, thereby freshening and purifying the air for the further use of animals. The first distinction is evident to everybody, the second is well known to the student of elementary chemistry. So far, so good; but there are some cases in which such broad principles as these may be difficult to apply correctly. There exists a somewhat mythic story about two Yorkshire boys, who went by dark to rob an orchard

of damsons—plummocks in the local dialect. The orchard was bounded by a stream (beck), and in the beck were “straddly becks”—frogs, to wit. Boy number one, up in the tree, gathered as fast as he could: boy number two, down in the grass, ate as fast as he could the share of the spoil that was thrown down to him. Dire misgivings seize boy number two, in consequence of a mysterious scratching in his throat as the damsons go down. “Tom! a’ say, Tom, ’as plummocks legs?” “Noa!” “*Then a’ ha’ swallowed a straddly beck!*” Broad principles failed to save this small youth from error; although he was certainly right in assuming that legs are structures proper to the animal as distinct from the vegetable organism, yet he was probably wrong (at least I hope so) in classifying his already swallowed specimens as members of the animal kingdom. For “plummocks,” if they have no legs, are possessed of stalks; especially when gathered unripe, as the spoil of the schoolboy thief is apt to be.

Similar mistakes might be made by too sweeping an application of the broad rules we gave above. For example, we might name animals that are fixed on stalks, and, therefore, capable of but very restricted movement (the so-called Zoöphytes, see p. 150); and we might run up a long list of plants capable of movement, which, nevertheless, are most undoubtedly not animals. Not only do a host of plants move in accordance with [the amount of light that falls on them, such as daisies and clover-leaves that shut up

at night, and sunflowers that turn to the sun; but some plants, such as the Sensitive Plant, will move when touched, closing their leaflets as if to shrink out of the way. A number of plants depend on a similar power for the fertilization of their seed; the mobile parts of the flower forming a sort of spring, of different construction in different kinds of flower, but in each case adapted to the one purpose of making insects the involuntary agents in the distribution of the pollen of the flower. Among these is the common Barberry, found wild in some parts of England, and often grown in gardens for its red berries, which make a pretty old-fashioned garnish when preserved.

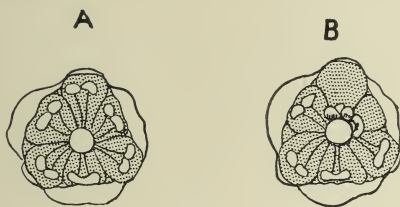


Fig. 1.—An Irritable Plant, capable of movement when stimulated—the Common Barberry (diagrammatic). A. Flower undisturbed. B. Flower after two stamens have been poked with a pin.

The flower, which appears early in June, has six stamens; if you poke the base of one, ever so gently, with a pin, it will bounce forward against the pistil of the flower and stand there stiffly. The same is true of the Pinnate Barberry, a kindred shrub, but a foreigner, with blue berries: only that the experiment does not always “go off” so certainly, because the flowers are sometimes found in bad weather to be

paralysed by the cold of our climate. The above are instances of *irritability*, that is to say, movement that occurs in response to some stimulus. Instances of spontaneous movement are seen in the spores of certain Algæ and Ferns (*zoöspores*, *antherozoids*, figs. 2, 3), which by means of *cilia* (see p. 137) swim about bodily from place to place with extreme rapidity: and more remarkable even than these, are some of the smaller algæ, which are round balls consisting of many little cells each provided with cilia, by the harmonious action of which the whole swims about in the water. So animal-like are these last-named forms (*Volvox*, *Pandorina*, see pp. 13, 14), that in some books they will even be found classed with animals¹ (figs. 3, 4).

Again, although as a rule the gaseous interchange of plant life is as stated above, yet Fungi constantly give off carbonic acid gas; so do the buds of flowers, and the germinating seeds of plants: yet these could not possibly be confused with animals.

The fact is, that although the majority of animals and plants are sharply marked off from one another, yet there are also certain broad characters which they share in common; and the two groups may be likened to two great branches that have spread in opposite directions from one hidden root. We must not be surprised to find a few intermediate twigs, given off from the parent stock half-way between them, scarcely

¹ For their place when classed in the vegetable kingdom, see Prantl and Vines' "Text-book of Botany."

to be classed as belonging to either one branch or the other, but bound to take a direction of their own.

From a strictly scientific point of view the crucial distinction between animals and plants lies in their chemical relationships, regarding which a few words of explanation must here be given. The food of plants consists of carbonic acid gas (carbonic anhydride, CO_2), water, and mineral salts;¹ the first is taken in by the pores of the leaves, the third (along with the water in which they are dissolved in the soil) by the fibrils of the roots. The mineral salts include compounds of nitrogen, which element is more or less entirely supplied to plants by derivatives from the ammonia and other nitrogen compounds contained in the decomposing sewage products of the animal kingdom. The food of animals, on the contrary, consists of water and organic compounds; and the animal body has no power to assimilate mineral matter, except in the case of its occasional artificial admixture with organic substances, as in the use of table salt or mineral medicines, or of its natural admixture in the fresh juices of plants and animals. These present a quantity of certain mineral matters, but in a state of mixture or perhaps sometimes of combination with the organic compounds, that especially favours their assimilation.

One of the differences between the organic compounds and mineral salts is, that in the former the

¹ The reader who is unacquainted with the terms used in Chemistry should refer to an elementary text-book dealing with this subject.

structure of the molecule is more complex, and it would seem that the animal body has not the power of building up complex substances unless part of the work is done for it; it can *alter*, as it were, but not *make* the necessary chemical structure.

The organic compounds referred to are of three classes. I. Proteids, or quaternary compounds (*i.e.* compounds made up of four factors, viz., carbon, hydrogen, oxygen, and nitrogen); these are practically identical with (dead) protoplasm, the universal substance of living organisms, which has been called the "physical basis of life," and of which more must be said hereafter; foods of this class may be obtained either from plants or animals, the protoplasmic basis being identical in both. II. Fats (sometimes incorrectly referred to as hydrocarbons), containing oxygen, hydrogen, and carbon; these also may be obtained from either plants or animals, being practically the same in both. III. Carbohydrates, or compounds of carbon with the elements of water in the proportion in which they exist in water: these are divided into two classes, namely, starches and sugars: the vegetable kingdom is the sole available source of either, for in the animal body sugar only occurs in rare traces, while the presence of any starchy compound is rare and exceptional.

The difference between the food of plants and animals, then, is shortly this: the animal requires its food ready made, in the shape of complex compounds; the plant takes up more simple compounds,

mineral salts, namely, and combining these with the elements of water and with carbon derived from the carbonic acid of the air, builds up the complex compounds that the animal organism requires for its food. Moreover, the two groups play into each other's hands, so to speak, as regards the waste products which result respectively from their chemical activity, or *metabolism*,¹ as it is called. Animal life may be compared to a fire: the final outcome of its chemical processes, fed by a constant supply of air, is a slow oxidation, which gives off heat, and sets free carbonic acid gas, to escape chiefly through the channel of the lungs or equivalent structures. Moreover, the protoplasm not only undergoes a constant waste and renewal of its carbon, but also at the same time of its nitrogen. The result is a residue of waste material, which is carried away from the animal body, dissolved in water, in the liquid excreta; its principal constituent is known as *urea*; it is a compound of the four elements, carbon, oxygen, hydrogen, and nitrogen, indicated by the formula CON_2H_4 , and may be artificially made; indeed it was the first organic substance that was ever prepared artificially by the synthesis of inorganic materials. In decomposition it forms ammonia; this, dissolved in rain water and filtering through the soil, supplies the various nitrates,

¹ This term (Greek *μεταβολή*, change) is used to denote the series of chemical changes which take place in a living body, and result in the transformation of the material of the body into new chemical compounds.

from which plants take the nitrogen required to build up their life-substance or protoplasm. They cannot derive it from any other source, for they are not able to assimilate the nitrogen of the air, as they do the carbon of its admixed carbonic acid (CO_2). Thus we see how perfectly interdependent are the two great groups of living things. The substance of the plant is the food¹ of the animal; the waste excretion of the animal helps to form the food of the plant. The waste gas given off by the animal (CO_2) is again the air-food of the plant: while the plant, in rejecting the balance of oxygen from the carbonic gas absorbed, supplies the oxygen by the constant inspiration of which the animal lives.²

¹ Primarily, in the phytophagous (vegetable-eating) animals indirectly, in the carnivorous animals which eat them.

² Guard against the error of saying that plants *breathe* CO_2 *instead of* oxygen. They require the presence of oxygen in the air, indeed their seeds will not germinate if it is not present; and their chemical activity, or metabolism, to some extent results, like that of the animal, in the formation of CO_2 . These facts represent the breathing of the plant, the respiration of vegetable protoplasm being, in short, the same as that of animal protoplasm. But in green plants, by day, it is entirely masked by the large inhalation of CO_2 and exhalation of oxygen which takes place in connection with the *feeding* of the plant, the green leaves of which are engaged in assimilating carbon. By night the assimilation of carbon stops, oxygen is therefore no longer exhaled in quantities, and the slight expiration of CO_2 begins to be perceptible. This is the foundation of the popular superstition that plants in a bedroom are unhealthy: a superstition quite without foundation, for the quantity of CO_2 expired under these circumstances is so small as to have no practical bearing whatever.

In these facts must be found the true and fundamental distinction between animal and plant. Yet even here we may find some exceptions to the rule. Plants of the class called Fungi, like animals, require at least a proportion of ready-made food: they feed in fact on animal or vegetable matter, some preferring sugar or jam, some animal substances, while some even attack living plants or animals. As has been already mentioned, these plants also give out perceptible quantities of CO_2 at all times, as other plants do only at night; and so do growing flower-buds and germinating seeds. In all these cases there is an accompanying perceptible evolution of heat, although in ordinary plant life the evolution of heat, like the production of CO_2 , is so small as to be scarcely perceptible.

Again, there are plants of much higher organization, which, in addition to the usual modes of root-feeding and leaf-feeding, take in animal food by surface absorption: such are the Fly-trap, and the Sundew, whose leaves have a special trap apparatus, sensitive like that of the flowers already mentioned, by means of which they catch flies, and absorb their juices. The Butterwort or Bog Violet (*Pinguicula*), which was formerly used as rennet¹ in England and is even now so used in Norway, has slimy leaves with incurved

¹ Rennet is the substance used in cheese-making to curdle the milk. Usually it is the lining of a calf's or pig's stomach, the gastric juice of which curdles the milk just as it would in the preliminary process of digestion; but there are a number of plants which may be used to produce the same effect.

edges, which perform the same function, although in a less perfect manner: the existence of rennet in the



Fig. 2.—Antherozoids, or Moving Spores of Mosses, strongly magnified; *b*, the mother-cell (*Polytrichum*); *c*, a free Antherozoid ($\times 800$) (*Funaria*). (From Sachs' "Text-book of Botany.")

plant is a curious fact in connection with this habit, its natural use being perhaps to digest the flies that are caught. Probably numbers of sticky glandular plants, such as the "Catchfly," which owes its name to this circumstance, are not above eking out their proper means of subsistence by absorbing the juices of such casual visitors as they happen to despatch by means of their stickiness. Besides these, again,

there are plants parasitic on other plants, such as Mistletoe; or partly parasitic, such as the Dodder, the Eyebright, the Yellow-rattle, and the Cow-wheat, that twine their roots round those of another plant.

The list of exceptions on the side of the animal kingdom is not so formidable; there are a few, which will be mentioned presently. Meanwhile it may be stated, that, in consequence of the resemblances existing between some forms, it has been proposed¹ to class the lowest forms of animal and vegetable life together as *Protista*; but this plan has not met with general favour. It is, indeed, more remarkable that such minute organisms can present so decisively and definitely, as many of them do, those differences

¹ By Prof. E. Haeckel.

which distinguish plants and animals, than that some of them should fail to present the whole set of these differences.

We need say no more about the distinctions or resemblances between plants and animals. They are not likely to trouble the student of Zoology, except on the field of the microscope. Here, it must be admitted,



Fig. 3.—A Moving Plant, and its Moving Spores (Zoospores). *Pandorina morum*, one of the Green Algae ($\times 400$). A, A motile colony; B, two zoospores in process of conjugation. (From Prantl and Vines' "Text-book of Botany.");

it is difficult sometimes for the beginner to tell which is which, or indeed, whether the object he is looking at is either one or the other. It is not without reason that one of the leading comparative anatomists of our day begins his course of instruction by pointing out the features which distinguish an air-bubble—which interesting object is not infrequently mistaken by the uninitiated for an *Amæba*; while every teacher of a

class in biology demonstrates, with a bit of gamboge, how very closely the *Brownian movements*—mechanical gyrations executed by minute particles of matter—may appear to resemble the gyrations of living organisms. But even those who have mastered the difficulties of

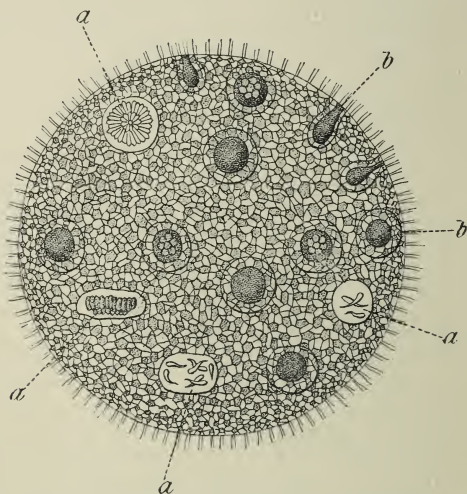


Fig. 4.—A Moving Plant. *Volvox*, one of the Green Algæ. (After Cohn, \times about 100, from Vines' "Student's Botany.")

the air-bubble and the Brownian movement, may be puzzled by such forms as those we have already spoken of—the motile spores of certain plants, or the motile kinds of Green Algæ. We have therefore figured some of these forms of vegetable life. The differences would be more readily apparent if the diagrams could be coloured. For the Algæ contain the green

colouring matter called chlorophyll (leaf-green), which is characteristic of nearly all plants except Fungi and parasites. This is distributed in granules. The few exceptions to this rule, that chlorophyll is characteristic of plants, include two freshwater animals, common in brooks, *Hydra viridis*, the freshwater polyp (see p. 160), and *Spongilla*, the freshwater sponge. Another distinction is the presence of a peculiar coating to the structural units of plants, which is called the cell-wall, and consists of a substance called cellulose (see p. 16). The existence of this can be demonstrated by reagents which colour it. We will now pass on to describe something of the microscopic structure of animals, for without a clear understanding of this, the structures which can be seen by the eye would have but little meaning for the observer. Nothing will be said here about the use of the microscope; but it will easily be understood that familiarity with its practical use is absolutely essential for the student of zoology. The reader who is not familiar with microscope work will find some useful information in Part III., chap. II.

CHAPTER II.

THE CELL AND ITS STRUCTURE.

THE substance of all living beings, whether plants or animals, is made up of **cells**. The name does not very appropriately describe what is meant by it; the reason of which is on this wise:—The existence of cells was first noticed in plants, and in plants each cell has a strong wall; the result of that is, that when the tissue is cut through, the contents inside the wall being often partially destroyed, or removed, and in any case chiefly of a fluid nature, the cells appear as hollows inside the walls, properly to be termed cells. Further investigation showed that the existence of the walls was, so to speak, accidental, and that the soft jelly-like contents of the cell were its essential part. In some plant-structures, and in animals, the small units of jelly were found to exist without those hard walls. The wall consists of cellulose, a purely vegetable¹ product: it may be detected by treating the organism with iodine. That substance, which affords

¹ With the exception of the *Ascidians*, among animals, which present a substance resembling cellulose in chemical composition (see p. 234); but it does not coat the cells, as in plants, but coats the whole animal, forming a skin.

the characteristic test for starch, by turning it blue, affords a test for cellulose by turning it yellow; but if next there is added a drop of strong sulphuric acid, then the cellulose turns blue. This reaction may be watched under the microscope in a unicellular plant or a bit of plant tissue, taking care to distinguish the tint of the cell-wall from that of the starch, which is coloured blue by the iodine alone. In vegetable cells there are spaces or vacuoles filled with sap; these are often so large that the protoplasm looks like a mere lining clinging to the cell-wall. Hence the protoplasm of cells was often spoken of, in the early days of biological observation, as the primordial utricle,¹ a name which may still be met with in some books.

Cells, except in a few exceptional instances, are so small that they cannot be clearly distinguished with-

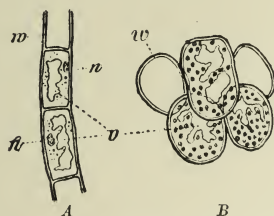


Fig. 5.—Typical cells of plants magnified to show protoplasm surrounded by a cell-wall. *A*, Cells from a hair of a thistle-leaf; *B*, cells from the tissue of a small green leaf. In the former there is no chlorophyll, and the nucleus is seen lying in the slightly granular protoplasm; in the latter the nucleus is not seen, being obscured by chlorophyll bodies; *v*, large vacuoles filled with cell-sap; *n*, nucleus; *w*, empty cell-walls. (For typical animal cell, compare and contrast Fig. 7, p. 22, and Fig. 10, p. 42.)

¹ Utricle, *i.e.* a little bladder or bag (diminutive from Lat. *uter*, a skin); primordial, *i.e.* belonging to the first construction (Lat. *ordior*, to begin a piece of weaving).

out the aid of the microscope; and hence the student of zoology requires to learn the use of the microscope. Cells of different kinds vary much in size, some being very much larger than others, and yet of microscopic size.

When not furnished with a wall of cellulose, the cell is simply a little mass of jelly, which has in its centre a dot, of varying size and shape, which is slightly darker than the rest, especially when the cell has been treated with staining fluid. This dot is called the **nucleus**: from the fact of its staining more deeply, and from its resisting the action of certain solvents, which by removing some of the surrounding jelly cause the dot to be seen more clearly, it is concluded that the nucleus consists of a firmer variety of the same jelly as the rest. Under a very high power of the microscope it is seen to be traversed by a network of darker (therefore no doubt firmer) material; and under certain circumstances, presently to be explained, this network develops itself into a set of definite shapes. The nucleus is to be considered the most essential part of a cell, for it is seen to initiate all changes connected with growth. In old cells it sometimes disappears, where the cell assumes some particular structure associated with some particular function, *i.e.* some particular *make* adapted for some particular *use*. An example of this is to be found in the fibres of voluntary muscle; these, when very young, are seen to consist of a number of cells with nuclei: but afterwards

the cells become crossed by bars in which the cell-substance assumes different optical properties, the nuclei disappear, and no one would dream the fibre to be composed of cells, had not its early stages been observed. Only a fibre crossed by bars remains; these bars have something to do with rendering the muscle contractile, but as yet it is not known exactly what they are. Besides these cases of old cells in which the nuclei have disappeared, there are rare cases in which no nuclei have ever been found:¹ it remains a moot point whether we are to suppose that a "cell" can exist without having a nucleus at any period of existence, or whether it may be expected that the existence of the nucleus in these forms will be demonstrated by some new method of treatment, or discovered at some stage of growth which has not yet been observed. In some cases the material of the nucleus is perhaps distributed throughout the cell, instead of being concentrated into one mass.

Be this as it may, it is certain that the nucleus is only a part of the jelly of the cell, of very much the same kind of stuff, only more active in its nature.

This stuff, the bit of living jelly which is called a cell, is what is termed **protoplasm**. Dead protoplasm (proteid) is found to be a compound of the elements carbon, hydrogen, oxygen, and nitrogen,

¹ See p. 140. Non-nucleated unicellular organisms are spoken of as cytods, *i.e.* cell-like bodies.

with also a little sulphur, and traces of phosphorus ; these are believed to be united in a very complex manner. In the living state it is believed to be likely that the very complex body protoplasm is further united chemically with the inorganic salts which in the dead state are obtained from it, when burnt, in the form of ash, and probably also with various organic substances. The living protoplasm is also full of fat granules, too minute to be dissociated from it for the purposes of analysis.

The whole of the animal body consists of a basis of this soft, half-fluid jelly-like substance, made up of cells, each with a separate life, activity, and set of movements of its own, and a firmer centre or nucleus, round which it is gathered. Thus the body of an animal (or plant) consists of a myriad of little units, each with a life of its own. One of them may die, and the others will take no harm : one of them may divide, and give rise to several new ones, without the rest being affected thereby. Since the name " cell " is a misnomer, because only the vegetable cell presents any hollowness, and that not always, it has been proposed to call the cells **plastids**.

Many cells have not only a nucleus, but inside the nucleus again another dot, believed to be yet again of darker and firmer material. This is called the **nucleolus** : it is present in cells which are preparing for very active growth, and in nerve-cells. When a cell is strong and vigorous, its rapid growth makes it necessary for it to divide, otherwise it would become

so large that the middle parts would get no oxygen and no food, on account of being so far from the surface. Division begins in the nucleus. This goes through a remarkable cycle of changes, to which has been given the name of **karyokinesis**, which means literally, *the activity of the nucleus*. As has just been stated, the substance of the nucleus is seen, when highly magnified, to consist of a network of fibres that stain dark in a material that stains more lightly; these are therefore called respectively *chromatin* and *achromatin*. When the nucleus is about to divide,

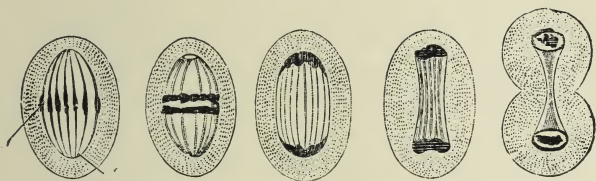


Fig. 6.—Successive stages of the division of the nucleus, showing spindle-shaped mass of achromatin, and dark masses of chromatin.

the chromatin forms a wreath at the outside of it, and then the loops of the wreath sharpen into points, so that it becomes a star, while the achromatin forms a long spindle-shaped mass which looks as if it were threaded through the wreath. The next change is that the chromatin star splits in half, and the halves travel towards the ends of the cell. Then the two new stars go back to the wreath form, and meanwhile the protoplasm of the cell is dividing across. When the halves are severed the new nuclei assume the usual shape.

Another feature often present in cells is the **vacuole**. This is a clear space which may contain fluid, or sometimes air. In plant cells there are often many vacuoles, so that the remaining part of the protoplasm is reduced to a mere set of threads passing between the spaces. The same is the case with some animal cells (see fig. 20, p. 76). In other cells a different kind of vacuole is met with, which is contractile. The vacuoles just described are fixed and do not move, but a contractile vacuole is formed when the surrounding protoplasm every now and then tightens round it, and squeezes it to nothing. The object of this is usually to get rid of some fluid the vacuole contains, thereby squeezing it outside the cell.

Amœba, one of the Protozoa, presents simply the

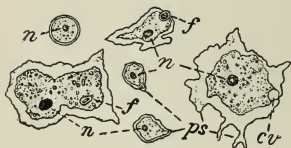


Fig. 7.



Fig. 8.

Fig. 7.—Magnified specimens of *Amœba* (small ones): *cv*, contractile vacuule; *n*, nucleus; *ps*, pseudopodia; *f*, small organisms taken in as food. The three smaller specimens are shown in a more or less retracted state, the two larger ones more active. All show an inner granular layer, the endoplasm, and an outer clear layer, the ectoplasm. (The boundary line between these appears in the cut somewhat too distinctly marked.)

Fig. 8.—Changes of outline presented by a single *Amœba*: 1 to 16, during a period of four minutes; 17 to 26, during a further period of three minutes.

cell-characters above described. Its protoplasm contains a nucleus and a contractile vacuule; it has the power of movement, and can temporarily push out parts of its substance (**sarcode**, as the protoplasm

of unicellular animals is often called) into long, irregular projections, called **pseudopodia**, or false feet. The use of them is to move with, or to catch food, if anything touches them. This animal is considered to present the most generalized form of the animal cell, from which all other forms are derived. Cells which closely resemble it are spoken of as amœbiform.

Most of the animals we are acquainted with consist of a vast number of cells; but some of the little animals that we can only see with the microscope consist only of *one* cell; and every animal, in the first stage of its existence, consists of only one cell, for this is the primary form of the *egg*. (See Chap. V.) There are some animals which consist of more than one cell, but not of very many; when this is the case, there is sometimes not much difference between the various cells. But where there are a vast number, as is the case with most animals, even very small ones, we find that different groups of cells undertake some special work of the animal body; and in order to do this, they become modified in some way that fits them for the special purpose, whatever it is, so that they assume a different shape and appearance from that of the ordinary type of cell.

Let us consider how many things there are for the animal body to do.

1. It has to breathe.
2. It has to feed.
3. It has to get rid of waste products.
4. It has to grow.

5. It has to feel.

6. It has to move.

The plant has to do some of these things as well as the animal; but the plant, unless we may give the Sensitive Plant and some others the benefit of a doubt, has not to feel; and, with similar exceptions, a plant has not to move. These things that have to be done, so long as the organism continues to live, we call its *functions*. The first four are vegetative functions; the two latter are animal functions. An animal that consists of *one* cell can do all these things; we may be rather sceptical about its feeling, but still the creature behaves as if it did, when one watches it under the microscope. It *feels* its way along; it *feels* a grain of material that happens to touch it, and throws out a "feeler" to touch it. About the *movement*, anyway, there is no question.

But when an animal consists of many cells instead of one, then these various duties, or functions as they are called, are portioned out according to the principle of the "division of labour." We have all been taught what the "division of labour" means, by an often-quoted example regarding the making of pins. Instead of one man doing all the required processes, and taking such and such time to do it, now, we were told, by the "division of labour" plan, one man makes the head, another man makes the pin, and another fastens them together, thereby saving all the time that used to be expended by the one man in changing from one process to the other, besides

saving time by the increased skill of the workman trained to one process alone. This example still holds good as an illustration, but it is quite obsolete as a description of the manufacture of pins, for it is so long ago since pins were made with separate heads, that I can only just remember hoarding up pins of this sort as occasional curiosities when I was a very small child. Pins are made all in one piece now, which saves the annoyance formerly felt when the head came off sometimes just when you wanted it to stay on—a part of the labour which was divided with the owner of the pin by nobody. But the principle is easily understood, however antiquated may be the illustration. As the result of the “division of labour” plan adopted among the cells of the animal body, we find cells which are respectively adapted for digesting, for excreting, for feeling, and for moving. When a large number of cells, all having one function, form a large group, we call this group an **organ** (instrument or machine); and an animal that has many different kinds of organs is spoken of as highly organized. But cells, like people, when they do one thing chiefly, learn to do other things badly; and the cell that is adapted for digesting, for instance, almost forgets how to feel, or to move, while the cell that is specially adapted for feeling almost forgets how to move, and so on.

Thus there are groups of digesting cells, forming gastric and other glands; groups of excreting cells, called kidneys; groups of cells that provide for the

production and growth of new individuals, called reproductive organs: the feeling cells form nerves, ganglia, and brains; the cells for moving form muscles. Then, because these groups of cells are now each cut off from the cells that perform other functions for them, they want special structures to provide for their special wants: lymph-vessels and blood-vessels, to carry them food, and connective tissue, to bind them together. Lastly, the whole body now requires gristles and bones, to support it; and a brain, to gather general information as to the feelings of all parts, and to send messages to tell the muscles how to move.

All these different things are formed by the growth and division and development of cells which were originally alike, a process shortly known as **differentiation**, *i.e.* the establishment of different parts, with distinguishing characteristics. This term may be applied to a single cell when its parts develop characters which distinguish them from one another, or, in like manner, to a whole organism. This process takes place during the egg stage of animal life, which will presently be described in full. (See Chap. V.) The young animal in the egg begins as a single cell; this cell divides to form a number of cells all much alike; then, when a large number of these have been formed, certain cells begin to take different shapes from others, and their differences increase until separate **tissues**, or masses of similar cells, are formed: and these, by progressive modifications, assume the char-

acters belonging to the adult form. If we arrange the various types of the animal kingdom in order, we may form them into a series somewhat comparable to the series of different stages shown by the young animal in the egg. That is to say, we may form a series of which the first and simplest kind consists merely of one cell, while the successive members of the series become by degrees more and more complicated. Only the series will not present *one* animal belonging to each stage of complication, but many and varied types belonging to each stage. We shall obtain a fairly correct idea of the necessary classification, if we imagine it represented as a tree, with branches, twigs, and leaves, of different ages, and situated at various levels; the lower levels representing the oldest and simplest types, the higher levels the newest and most complicated types. We cannot frame a classification by which we shall pass simply step by step from one stage of animal type to the next higher stage; but we have to deal with collateral branches, and with all sorts of twigs and offsets from them (p. 305).

In order to understand classification, we must first understand something about the different parts and organs which go to make up the animal body. As has been already said, an organ is a part of an animal consisting primarily of a group of cells of similar kind, which are modified so as to be especially suited to perform some special portion of the work of maintaining life. The study of the uses of organs is called **Physiology**: its object is, to find out what are

the essential processes of life, and hence what life is. The study of the arrangements of organs is called **Morphology** (the study of form); a new word, which has to some extent superseded the older name of Comparative Anatomy: its object is, to find out how animals are related to one another by the comparison of their parts. Classification is just a short way of expressing the facts of Morphology: we put all the animals that have their parts arranged in a similar manner into one group, and give the group a name. The study of the classification of the animal kingdom is called **Systematic Zoology**.

CHAPTER III.

THE STUDY OF ORGANS.

THE following is a short summary of the chief of the different parts of a highly organized animal. Except where the contrary is distinctly stated, the structure described is that of a mammal, the highest form of the vertebrates or animals with backbones. It is easier to bear in mind the parts of a more complicated kind of animal, and then think of all the less complicated kinds as leading up to this type, than to learn the animal series from its simpler types, and note the development of the different tissues and organs as they appear one by one in the series.

The lowest forms of animals, called the Protozoa, are for the most part unicellular, or consist of compound aggregates in which separate cells cannot be distinguished. The rest of the animal kingdom, which are possessed of multicellular bodies, are called the Metazoa. Of these, the lower forms (Coelenterata) consist practically of two layers of cells, and are therefore spoken of as **diploblastic** animals; while the rest, possessing a more complicated structure, are spoken of as **triploblastic**, or three-layered. (See figs. 11, 12, p. 46.) The vertebrate is of course included among the latter.

A vertebrate affords the most familiar type of highly organized animal; but it must be borne in mind that there are other animals almost equally highly organized, but differing widely in the arrangement of their organs.

First it must be stated that the young animal in the egg (embryo) consists, at a very early stage, of three layers, spoken of as the **germinal layers**: viz., the outside, or skin layer, called **Epiblast** (see figs. 23 and 24, p. 113); the middle, or muscle layer, called **Mesoblast**; and the inside, or stomach layer (which gives rise to the glandular organs), called **Hypoblast**. The first and last are the two primary layers, and the second is formed afterwards. All the parts of the full-grown animal are derived from one or other of these layers; and although in the full-grown animal the parts respectively derived from each of the three layers are all mixed up together, yet it will simplify the student's task to group them according to their origin, which otherwise would have to be learnt separately.

Parts derived from the Epiblast. The epiblast of the embryo forms the skin of the adult animal. The most obvious use of the skin is to protect the tissues inside it. For this purpose the cells of its outer layer (**epidermis**) become loaded with a hard substance; in the vertebrata (back-boned animals), this is a substance called **keratin**. In the invertebrata it is a substance called **chitin**. The latter differs from the former in being more usually associated

with earthy matter, forming a shell (as in the lobster): it is less easily destroyed by chemical action. Fur,

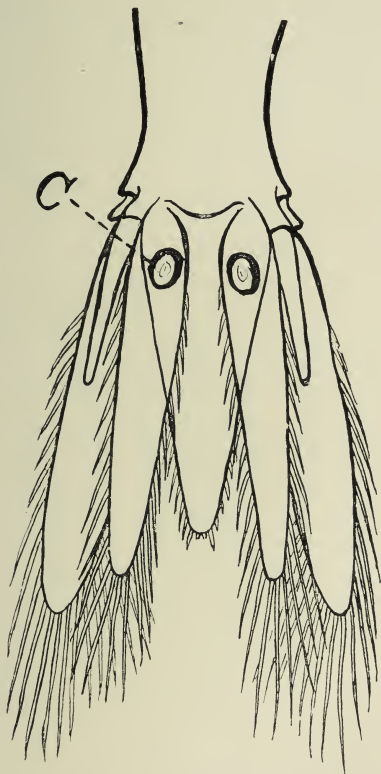


Fig. 9.—Rudimentary ears or otocysts, *C*, in the tail of a crustacean, *Mysis*, the Opossum Shrimp. See next page.

finger-nails, and feathers, are all modified appendages

of the epidermis, and all contain keratin. Similarly the hairs of invertebrate animals, such as the lobster, are strengthened by chitin. The skin has not only to protect the body, but it has also *to feel* for the body; it is the organ of touch, and in the highest animals is full of nerves. The hairs which appear on the skin, though usually merely a protection, are sometimes organs of sensation of some kind, with little nerves at the base. Thus, the cat's fur is protective, and her whiskers sensitive. We speak familiarly of the five senses, sight, hearing, taste, smell, and touch: the four latter senses are conveyed through cells which are specially modified skin cells, with their appendages. In the invertebrata we find comparatively rudimentary sense-organs, consisting of cells with hair-like processes. A cell with one of these processes is the primary and simplest form of sense-organ. The **ear** is formed by modification and multiplication of such cells in connection with some arrangement for magnifying the force of sounds. The simplest form of ear is an **otocyst**, or cavity, containing a small solid body, called an **otolith** or ear-stone, floating in a surrounding fluid. In fig. 9, p. 31, are shown the otocysts of *Mysis*, the Opossum Shrimp, which are situated, strange to say, in its tail. The long hairs which fringe the flaps of the tail doubtless assist the perception of vibrations.

The sense of taste, in ourselves, is accomplished through the means of delicate elongated cells aggregated into a round mass; these are called **taste-**

buds; the **olfactory bulbs**, and **touch corpuscles**, by which we receive respectively the senses of smell and touch, are built on a similar plan.

When a sense-organ, as in its lowest forms, consists merely of an irritable cell, its usefulness cannot be very great. To warn the animal of the presence of danger or food, and to enable the animal to profit by the warning, so that it may *feel* and *act*, not merely *shrink* and *shrug*, communication between the different parts of the body is required, and especially communication between its sense-cells. This is supplied by **nerves**, which also are originally derived from the epiblast (figs. 23 and 24, p. 113). Long threads, called nerve fibres, pass to peculiar large branched cells called **nerve-cells**. A group of nerve-cells is called a **ganglion**; a band of nerve fibres, passing between opposite or adjacent ganglia, is called a **commissure**; and a large number of united ganglia, united by many commissures, is called a **brain**. The brain attains its highest development in mammalia and birds. It is customary to restrict the application of the term to the vertebrata only; but there is no reason why the mass of ganglia contained in the head or anterior region of most of the invertebrate animals should not also be called a Brain. It would lie beyond the scope of a little book like this to discuss at any length the functions of the brain and its connected system of nervous fibres. Briefly, we may say that its primary function is double: it has to *receive* and put together messages of sensation (sensory impulses),

and to *send out* messages of action (motor impulses). It is the seat of sensation and the source of movement: the organ of *feeling* and of *will*. Its two functions are accomplished through nerves which in the vertebrata can be distinguished as **sensory nerves** (afferent nerves) and **motor nerves** (efferent nerves).¹ If we ask how far the terms *feeling*, and *will*, and *consciousness* are applicable to forms of life in which the nervous system is developed only in rudiment, or, as in the unicellular and some other organisms, not developed at all, we open up a wide field for discussion. Many of our own actions, such as winking the eyes and breathing, are performed involuntarily and unconsciously, while vital processes, such as the beating of the heart, are not only performed involuntarily and unconsciously, but independently of our control. Actions of this sort are called **reflex actions**; and it is believed that they may possibly have come to be eventually performed in this unconscious way by having been performed so very often, not only by ourselves but by an untold number of our ancestors. This may be supposed possible when we consider that anything we do very often

¹ Afferent (Latin, *ad*, to; and *fero*, carry), carrying inward-tending, or centripetal impulses, because the sensory impulses are carried from the outside to the centre of consciousness. Efferent (Latin, *ex*, out of; and *fero*), carrying outward-tending, or centrifugal impulses, because impulses which produce movement are carried from the brain outward to the various movable parts of the body.

gets to be performed unconsciously; thus, for instance, in walking, though every step is a voluntary act, we forget it, and can think of other things as well as if we were standing still.

In the animals which have the body composed of a series of joints (segmented animals) there is a chain of ganglia all down the body corresponding with the joints, united by nerve cords. The brain is in these a specially large ganglion, or the union of several ganglia modified by their relations with the mouth. In vertebrates, or back-boned animals, which in some respects resemble segmented animals, the brain is much more complicated, and the string of ganglia is replaced by one thick cord; but the latter shows its compound nature by the fact that it gives out at regular intervals a pair of branches, one at each side. Each of these branches springs from a double root; and the anterior, or front part, of this root contains only motor nerves, and the posterior, or back part, only sensory nerves.

Nervous tissue is chiefly made of a kind of fat containing a good deal of phosphorus, and almost identical in composition with the yolk of egg.

The **eye** arises in the vertebrate embryo as an outgrowth of the brain, supplemented by an ingrowth of epiblast forming the lens. The simplest forms of eye, called ocelli (little eyes), found in the lower invertebrata, consist of a pigment spot, overlying the termination of a cutaneous nerve. Several different types of eye are formed among the higher inverte-

brata; of these perhaps the most remarkable is the "compound eye" of insects.

Parts derived from the Hypoblast. The lining of the digestive tube, through which food passes, consists of a layer of cells called **epithelium** in the adult animal, and hypoblast in the embryo. It is the digestive layer. The tube itself is called the **Alimentary Canal**.¹ In simple animals it is merely a straight tube. In the higher vertebrates it is immensely complicated. Its chief parts are the **stomach**, or **gastric** region, which is adapted for the digestion chiefly of proteid foods (see p. 8), and the **intestine**, a portion adapted for the digestion of all sorts of food. This is convoluted or straight, ac-

¹ It is also spoken of as the Gut, in which three regions are distinguished—the Fore-gut, Mid-gut, and Hind-gut. The use of these terms is chiefly restricted to embryology.

It is usually understood that the mid-gut comprises the true alimentary canal lined by hypoblast, while the fore-gut and hind-gut are formed by inlets from the epiblast, which form respectively the mouth and excretory opening (anus), and are called the *stomodaeum* or *stomatodaeum* and *proctodaeum* (Gk. *στόμα*, mouth; *πρωκτός*, anus). The extent of these regions varies greatly in different types of animal, and hence there is some ambiguity in the use of the terms fore-gut and hind-gut. It may be noted that the use of those terms is an instance of the reaction which has of late taken place against the exclusive use in scientific nomenclature of words derived from the Latin and Greek. In imitation of the example of the Germans, an attempt is sometimes made to utilize popular English names; but the possibilities of their use are very limited, and even where they can be used the effect is not always happy.

cording as to whether the food is, or is not, of a kind that requires long digestion in the intestines; in man and other mammalia it is slung in its place by delicate transparent membranes, called **mesenteries**. Between these two regions lie two large **glands**,¹ the **pancreas** and the **liver**, which communicate with the alimentary canal each by a tube, called its **duct**. The cells of the pancreas secrete a fluid called **pancreatic juice**, which is alkaline in reaction. Its use is to complete the digestion of the starchy foods, and also of any proteid food that the stomach has not already disposed of.

The **Liver** secretes and pours into the intestine the substance called **bile**, which is also alkaline. This substance aids the digestion of fats. It may be described as a by-product of the animal economy; for there is room to believe that the liver manufactures the bile out of the waste and worn-out portions of the blood. One of the chief reasons for thinking so is, that one of the colouring matters of the bile is identi-

¹ Glands are organs consisting of numbers of cells which have the work of secreting (separating or hiding away a store; Lat. *secretus*, from *secerno*) from the blood some substance which is of use to the body, such as gastric juice, mucus, bile, etc. The name gland (Lat. *glans*, a nut or acorn) was given them because the glands first noticed by anatomists were organs that consist of a small hard round mass like a nut. Hence, a layer or mass of secreting cells is called glandular tissue, and a single secreting cell a glandular cell. The appearance of such cells under the microscope is peculiar and easily recognized.

cal in chemical composition with a substance which is found in old blood-clots. The liver, therefore, has a double work to do: to cleanse and filter the blood, and to make something new and useful out of the waste residue which it has withdrawn from the blood. Hence it is a very important organ, and is connected with very important blood-vessels.

All these organs belonging to the alimentary canal are lined with the peculiar cells of the digestive layer. To save room, the cells are grouped in little pockets, which are called **glands**; when they are very long, as in the intestine, they are called **villi** (Lat. *villus*, a hair, pl. *villi*). The secreting cells consist of a clear transparent protoplasm, which is very active in its chemical changes, becoming full of fat granules as soon as it absorbs anything.

These cells are also the channels of absorption. They suck in the fluid products of digestion, and transfer them to the lacteals of the lymphatic system (see p. 45).

Besides these, the mouth is provided with glands called salivary glands; the moisture of the mouth, which they secrete, is called **saliva**, and contains a ferment called ptyalin, which digests starch, and changes it into sugar. The secretion of the stomach, called **gastric juice**, contains hydrochloric acid, and a ferment called **pepsin**, which digests proteid food (see p. 8); the ferment of the pancreatic gland is called **trypsin**; as already stated, it helps to digest both. In this it aids the juice secreted by the

glandular lining of the intestine, which is called the **succus entericus** (intestinal juice).

There are other glands besides the digestive glands; but all consist, like these, of highly active cells, which make some special substance, and either pour it direct into some special organ, or transfer it by a special tube (duct) to its destination.

The alimentary canal is sometimes provided with an appendage called a **cæcum**, because it consists of a tube with no opening (*i.e.* blind) at the far end. This is another arrangement for securing the greatest area of digestive surface with the least possible waste of space. The rabbit has a very large cæcum.

The **Lungs** of vertebrates are also formed from the hypoblast. They consist of a complicated system of branching air-chambers lined by a continuation of the same epithelium. No organ perhaps is so variable throughout the animal kingdom as the breathing organ. While the higher vertebrates have lungs, the lower ones have gills, and the intermediate forms (Amphibia, frogs and newts) have gills first and lungs afterwards. The lung is not developed from the gills, but is an independent organ situated in quite a different place. Among the Mollusca or shell-fish, the marine shell-fish have gills, and the terrestrial shell-fish lungs in a corresponding place. Among the segmented animals, insects have breathing-tubes opening in a row on their sides, while the aquatic larvæ of some insects¹ breathe

¹ *E.g.* dragon-fly and gnat.

through the intestine ; lobsters have gills attached to their legs. Whatever the form of the respiratory organ, it is always such as to bring the blood to a thin layer of cells, through which oxygen can pass from the air or water ; this layer is folded so as to afford as large a surface as possible. The breathing organs of vertebrates are exceptional in being derived from the hypoblast, those of invertebrates being usually derived from the skin-layer.

Among parts derived from the hypoblast must be mentioned the **notochord** of vertebrates, a structure of which more will be said hereafter (see p. 76).

The space between the alimentary canal and the body wall is the **body cavity**, or **cœlom**, as it is variously called (Fig. 12). It is a very important feature in the arrangement of the internal organs ; and its nature can only be understood from a study of its arrangement in primitive animal types, and of the way in which it is formed in the embryo. The hydroid animals (*Cœlenterata*), instead of having an alimentary canal lying in coils inside a body cavity, a tube fastened within a hollow space, have only a simple cavity (Fig. 11). The early embryonic stages of many animals are formed like this, and the cavity is called the **archenteron**, or primitive stomach ; the cells which line it are the hypoblast or stomach layer. In some cases it appears that this archenteron afterwards branches into two other portions besides the main one, and these two gradually extend till they go all round the main portion, so that the whole arrange-

ment is like a little bag with two other little bags lying one on each side of it. Then these two other little bags grow larger and meet; at the place where they meet, their walls part, so that they become united; meanwhile, they lose their connection with the main cavity at the opposite side, but retain their connection with one another. Thus they entirely surround the chief bag. This last, sometimes called the *mesenteron*, is the alimentary canal, and the hollow that rings it round is the body cavity. The lining of the body cavity, including the covering of the mesenteries (peritoneal epithelium),¹ therefore, belongs originally to the hypoblast layer; it receives the general name of the **coelomic epithelium**. It is very thin, and all the supporting part of the wall of the body cavity belongs to the mesoblast layer.

The growth of the body cavity may take place in other ways; but the above² is believed to represent its primitive mode of formation. Thus the alimentary canal and the body cavity are both differentiated from the primitive archenteron, which corresponds with the enteron of the *Cœlenterata*. Hence it is that the

¹ The name epithelium was originally given to the ciliated or glandular cells lining the various internal cavities of the body. The term is now applied not only to these, but also to surface cells belonging to the outer body-layer.

² When the body cavity is formed in this way, it is called an **enterocœle**; when the steps of its development are shortened, so that it is first seen to appear as a slit surrounded by mesoblast tissue, it is called a **schizocœle**, or "split-cavity"; this is the case in vertebrates (see p. 113).

latter is sometimes referred to as the body cavity, sometimes as the stomach, the animal being said to possess no body cavity.

Parts derived from the Mesoblast. At a very early stage of the embryo, the mesoblast is formed between the two primary layers (see p. 30). At first its cells are all alike, but afterwards they develop into tissue of different kinds, including the supporting tissues of the body, namely connective tissue and bone, and the muscular tissue. Connective tissue is a thin transparent tissue, which binds together all the other parts.

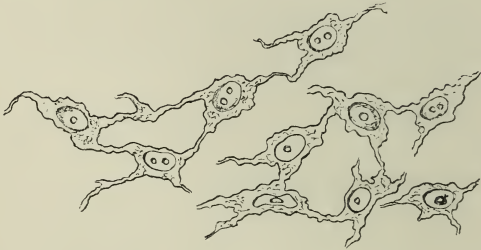


Fig. 10.—Typical **Mesoblast** Cells (see p. 72) from an embryo chick of three days' incubation, highly magnified. The large oval nuclei of the cells have a round nucleolus, or sometimes two.

Muscles are of two kinds. The smooth muscles perform the actions that are not governed by the will, and are called reflex actions. They are called the involuntary muscles.

The other kind, known as the voluntary or striped (striated) muscle, composes the mass of what we usually call "the muscles." These are striped with rings

which appear alternately light and dark under the microscope, because the substance of the rings possesses the peculiar optical property known as "double refraction." These muscles are formed of fibres, in which the original cellular structure is lost. The striped muscles are best seen in insects, which seem to have them brought to the greatest perfection both in form and use, since insects are the strongest animals known, for their size.

We must not look upon muscles as mere filling-up stuff; they may be called the **organs of action**; they are the special tools of the will, and are all the more interesting because of their curious and complicated structure, which is as yet not thoroughly understood.

To the mesoblast layer belongs also the **dermis**, or lower layer of the skin of vertebrates, with the various structures derived from it.

The muscles in vertebrate animals are supported by **bones**. Bone consists of cartilage or gristle, in which mineral matter has been deposited; this process is accomplished by special cells, called osteoblasts. In the body of the higher vertebrates, nearly all the gristle is thus turned into bone in the adult animal; but in some of the lower fishes the bulk of it remains gristle. In the invertebrates, bones are not found, except in the case of the cuttlefish. There are a few bones which are not ossified from gristle, but from a kind of fibrous tissue or membrane. They are *scales* belonging to the lower skin or dermis, which have

passed down into the muscles in the course of development. The distinction between these bones, called **membrane bones**, and true bones, called **cartilage bones**, is extremely important to remember, as will be seen when we come to a later chapter (p. 261). But there are very few membrane bones, compared with the number of the true bones.

The **Blood** also belongs to the mesoblast layer. Like gristle or skin, it is really a *tissue*, consisting of similar cells; only the cells do not stick together, but flow about in a liquid medium.

The blood of vertebrates contains two kinds of cells, or corpuscles as they are called, the red and the white. The latter come from the fluid lymph (about to be described), that overflows after receiving the products of digestion; hence there are always more white corpuscles to be found in the blood shortly after a good meal.

Besides the blood, vertebrate animals have another fluid called the **Lymph**. This is a white fluid with white cells floating in it, instead of red ones, as in the blood. These cells are very like the *amæba* which we have spoken of as one of the simplest types of the unicellular animal organism, except that they have no contractile vacuole. They are called **lymph corpuscles** or **leucocytes**. They are formed inside certain structures that are known as the **lymphatic glands**, which are situated in all parts of the body, embedded in the muscles and connective tissue. These glands communicate with each other by pipes, like

blood-vessels ; but instead of ending, like the blood-vessels, in fine hair-like branches, called capillaries, they end in irregular spaces. The division of the nutritive fluid system into two kinds, lymph and blood, is peculiar to the vertebrates. The glands and vessels are in close connection with the **villi** of the intestine, by branches called **lacteals**, through which they receive from the villi the liquid products of digestion, which the villi absorb from the inner surface of the alimentary canal. Thus the lymph is replenished with liquid from the alimentary canal, and with cells from the lymphatic glands. All the small branches of the lymphatic system join on the left side to form one vessel, called the **thoracic duct**, because it lies in the region of the thorax (chest), and there opens into the internal jugular vein of the blood system. There is a similar but much smaller and less important vessel on the right side. The system of blood-vessels is closed all but these openings, through which it is replenished with fluid and with white corpuscles.

The **Blood** is contained in a system of vessels which in the higher animals have contractile walls, that drive the contents along. The **heart** is in its simplest form merely a tubular contractile vessel, that becomes in mammalia complicated into four chambers, two auricles and two ventricles ; this structure is produced by the tube twisting and doubling upon itself during the course of its development. The vessels which take the blood out of it are called **arteries** ; these pass to all parts of the body and divide into capillaries (*i.e.*

tubes as fine as hairs); then these capillaries run together again, joining again and again exactly as they

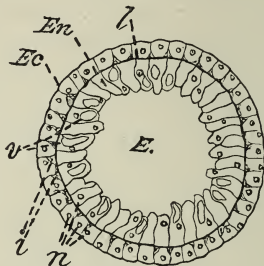


Fig. 11.—**Diploblastic** animal with no separation between body cavity and alimentary canal—transverse section of *Hydra*, magnified: *Ec*, ectoderm (epiblast); *En*, endoderm (hypoblast); *E.*, enteron or digestive cavity (see p. 40). *n*, Nuclei of cells; *v*, vacuoles of endoderm cells; *l*, supporting lamella (see p. 130).

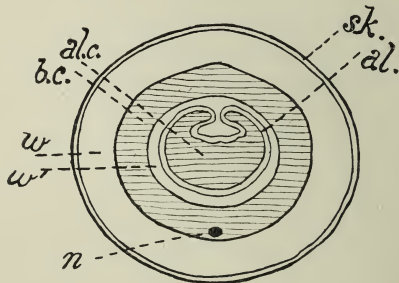


Fig. 12.—**Triploblastic** animal with body-cavity (p. 40) and alimentary canal. Plan of transverse section of Earthworm (see p. 132): *b. c.*, body-cavity (shaded) surrounding *al. c.*, cavity of the alimentary canal (shaded); *sk.*, the skin, represents the outer body-layer, ectoderm or epiblast, and *al.*, the lining of the alimentary canal, represents the inmost body-layer, endoderm or hypoblast; between these lie the structures comprised under the term mesoblast, including *w*, muscular portion of the body-wall, and *w¹*, muscular portion of the wall of the alimentary canal. The longitudinal nervous system, *n*, is ventral in position. (The scale of the diagram is not large enough for cellular structure to be represented.)

before branched, to form **veins**, which carry the blood back to the heart.

In the embryo the red corpuscles of the blood arise in the inside of large branched mesoblast cells, which are called "blood-islands." It is not quite certain how they arise in the adult: there are several conflicting theories; one theory is, that they come out of the splenic or some of the lymphatic glands, another, that they are formed in the marrow of bones, and yet another, that they are formed in some way from the white corpuscles. In mammalia, they have no nuclei. The majority of invertebrates have blood with white corpuscles, often of stellate or amœba-shaped form; if colouring matter is present, it is usually in the fluid of the blood. The colouring matter is not always red; in some invertebrates it is green. Some worms, however, have red blood; a significant fact, compared with what is stated elsewhere as to the relation of the vertebrata to this group. The use of the colouring matter of the blood, wherever situated, is as a carrier of oxygen. It consists of a substance which unites readily with oxygen in the respiratory organs, parts with it as readily to the body in the course of the circulation, and then renews the supply.

The **kidneys**, or excretory organs, and the **re-productive organs**, must also be mentioned in our list of the organs of the body. While in vertebrates the excretory organs take the form of a pair of oval masses of minute and extremely convoluted tubules (little tubes), in the higher worms they exist as a series of isolated pairs of tubules situated in successive rings of the body. These are called

nephridia, or little kidneys; or, from their position in successive segments or rings, the **segmental organs**. These are regarded as a primitive type of excretory organ, from which the kidneys of other types, including vertebrates, have been formed by various modifications. In bivalves there is a paired kidney called the organ of Bojanus, and in the lobster there is a paired kidney called the green gland, which is remarkable for its anterior position, being situated near the front of the head.

While there are some of the tissues of the animal body that can be satisfactorily examined under the microscope in a fresh state when divided into minute portions, there are others that require to be subjected to the action of various reagents before their structure can be clearly shown. By means of a razor, fixed in a machine called a microtome, tissues which have been suitably prepared are divided into transparent sections thin enough to be examined under the microscope. The knowledge of these processes and their results constitutes the science of Histology.

The whole bodies of minute animals are also in the same way divided into sections, and mounted so that they are preserved from change, and can be studied at leisure. Some knowledge of these processes is necessary for the student of Zoology; the beginner, who is ignorant of them, may as a first step to knowledge obtain ready mounted sections of tissues, and of various animals, for examination under the microscope (see Part III. chap. II.).

CHAPTER IV.

THE ORIGIN OF SPECIES.

The Origin of Species. The different *kinds* of animals are spoken of as *species* (see p. 122). It was formerly supposed that these kinds or species were essentially distinct; and that the differences between one kind and another were immutable, and had existed ever since the origin of life on our globe. Up to the end of the last century such a thing as *transmutation of species* had only occasionally been suggested, and such suggestions had been made in a vague way, and without any reference to carefully verified data. The first zoologist who obtained a real insight into the origin of species was Lamarck; but his speculations were known only to a few philosophers, and had never reached the world at large. The same was the case with the tentative speculations of several other writers.

In July, 1858, the late Charles Darwin and Mr. Alfred Russel Wallace simultaneously laid before the world¹ a synthesis and an interpretation of certain scientific facts which revolutionized pre-existing ideas as to the nature and origin of the world of living

¹ Namely in papers read before the Linnean Society.

organisms. That interpretation has been accepted by every zoologist¹ as the key which shows order and beauty in what were previously the almost chaotic details of natural history. It may briefly be summed in the following words.

Every plant and animal under favourable circumstances produces, to succeed the two parents, a plurality of offspring, some kinds an immense number of offspring.² The result is, a "struggle for existence" among the numerous offspring, each striving with the others for place and food. In this strife, the slightest circumstance in which any individual differs from the others will turn to its advantage or disadvantage, as the case may be. Now, no two individuals are quite alike, and no offspring precisely resembles its parent; to this tendency of individuals to present individual peculiarities not derived from the parent, Darwin gave

¹ Two or three names might be given as exceptions, but it would be difficult to find a fourth.

² "Every organic being," Darwin wrote, "naturally increases at so high a rate that, if (they were) not destroyed, the earth would soon be covered by the progeny of a single pair. . . . The elephant is reckoned the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase; it will be safest to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old; if this be so, after a period of from 740 to 750 years there would be nearly nineteen million elephants alive, descended from the first pair."—*Origin of Species*.

the name of **variation**. Among the slight differences which occur, the favourable ones are shown by the survival of the individual, the unfavourable ones by its death. Now, although offspring do not precisely resemble their parents, yet they do so in the main; and any one particular characteristic has its chance of being inherited; and if inherited, it will again and again be picked out for possible inheritance by the survival of its possessor, when other individuals that are without it die and leave no offspring. In this way, the "struggle for existence" results in the "natural selection" of individuals possessing certain qualities, and in the "survival of the fittest" to contend with the given circumstances of the kind of animal or plant concerned. By this process the characters of a race of animals or plants may, in an æonic period, be entirely changed. That the processes of *artificial selection*, undertaken by gardeners and breeders of stock, have resulted, and do commonly result, in the production of new kinds, everybody knows. The steps by which this result is attained are practically identical with what has just been described. Every individual that does not possess a certain given characteristic is weeded out; it is destroyed, and leaves no offspring. In time is thus produced a kind, or breed, which has the desired characteristic fixed. Thus we get distinct breeds, for instance, of pigeons or of dogs, so unlike that if found wild they would be called different species. The short-nosed pug and the long-nosed collie, the tiny timid lapdog, that shivers in its silk-lined basket,

and the huge St. Bernard, brave and fearless of cold, and weighing, like the prize dog "Plinlimmon," a couple of hundred pounds, are the opposite results of artificial selection—results so opposite that we might assign them, not merely to distinct species, but to distinct genera, if we did not know how such varieties can be produced by artificial selection. Similarly, in the region of vegetable life, we find that from such wilding stocks as the crab and the sloe have been produced by artificial selection the many varieties of the apple and the plum.

In some cases, such as that of the pigeon and the fowl, it is easy to compare the variant race with the original stock ; in other cases, the variation produced has been so great that we are left in doubt as to the original form. It would perhaps be taking an optimist view of the character of either the wolf or the jackal, if we allowed either of them to claim precedence over the other as ancestor of the dog ; and there are other cases regarding the origin of which we must similarly remain at present in a state of uncertainty. One explanation of the very wide variation produced by selection lies in the following facts. One definite characteristic, by a mysterious sympathy, or "correlation of parts," often involves the existence of another ; thus, for instance, animals that are deficient in hair are apt also to be deficient in teeth. Hence the intentional selection of *one* character may result in the unintentional selection of others ; and thus, in consequence of this correlation of parts, the new race pro-

duced by breeding with a view to one characteristic often differs all round from the parent stock.

Theory of Evolution. To trace the analogy between the work of the gardener or the cattle-breeder and the work of nature, and to interpret nature in the light of this analogy, was the great task of a great and patient mind. One principle is seen underlying that analogy, the principle, namely, that the existing forms of life, in their infinite variety, have been produced, and are still in course of being produced, by the infinite modifications of outward circumstances, from other and different forms. One conclusion is inevitably suggested by this, namely, that all forms of life have in the distant past diverged gradually from a common source.

Some glimmering of these ideas had found its way into the minds of previous writers ; but it was Darwin's wide knowledge of the facts of nature which gave them the clear intelligible form and the tremendous evidential force that ensured their reception by open and candid minds. They were in harmony, too, with the aspirations of the modern world ; they seemed the very embodiment of the spirit of the age. In the light given by these ideas, not only were existing systems of natural history revolutionized, but also existing modes of thought. Never was novel truth more gladly welcomed by an eager world, or more readily incorporated into the intellectual life of the day. And never, since the time of Galileo, was a novel exposition of scientific facts so virulently attacked by those who

had reason to fear the daylight of truth and the fresh air of free opinion, or whose vanity led them to suppose that in defending their own ignorant prejudices they became thereby the champions of sacred and holy things. The arbitrary bounds of species, fixed as they had been often by the limited knowledge, and sometimes by the unlimited pedantry, of the science of a previous age, were consecrated as a sort of "Luck of Edenhall," with the destruction of which all the hopes of the human race would somehow vanish, and leave the world a howling wilderness. The "Darwinian theory," and the negation of it, became the shibboleths of opposing creeds: somewhat to the distress of the author of the theory; for his mind, like that of nearly all truly great men, was constructive rather than destructive in its energies, and he was not iconoclastic. Few great men are; for why should those who can plant a truth that is new waste their time in hedging and ditching by the wayside of philosophy, hacking away rotten branches from the old?

Embryology as a key to the facts of Evolution. While a great impulse was given to the study of natural history by these new ideas, numbers of discoveries were being made which tended to confirm them. Some of these were discoveries in the popular sense of the word—discoveries of types of plant or animal which had not been found before; but other and more valuable discoveries were made when the insight of the investigator was directed to the study

of familiar things. The most remarkable additions to previous knowledge regarding the world of living things were those made by the study of the development of the young animal. We must for the present defer any detailed account of this branch of zoology, which shortly attained the rank of a separate branch of science; but something may here be stated regarding the general laws of development which have been formulated as a result of the facts observed. The development of a young animal, or plant, in its passage from its early and simple to its final and complex form, presents, as has been already stated (p. 27), a series of stages which afford a striking parallel to the artificial series given by a classification such as is generally adopted by zoologists, in which the various types are so arranged as to exhibit a gradual progression towards the most perfect and complex form. That the character of the immediate parent is, in the course of an individual's development, the last to assert itself, we know from the facts of common observation. Thus, the "family likeness" comes out late in life in human faces which, when young, seemed to bear no resemblance to the parents. Thus, also, you may often trace in the fur of the blackest kitten of the black cat, when it is only a few days old, indications of the stripes which were the characteristic of its striped ancestor. Similarly, foals show stripes which indicate the descent of the horse from a striped zebra-like ancestor. As the kitten or foal grows older, these stripes disappear; in brief, the character of the

far-away ancestor is dropped, and the character of the immediate ancestor is attained. In other words, there is a point in the development of an individual at which it assumes the characters of its immediate ancestors; and if we "hark back" from this point, we come across the characters of more remote ancestors. We may reason from the analogy of these facts, and draw similar conclusions regarding the origin of the successive stages presented by the embryo in the egg. For instance, when a hen's egg has been incubated for three days, the neck of the enclosed chicken exhibits on each side a set of holes or gaps, with straight blood-vessels running between them. These are correlative in their position, and in the distribution of their blood-vessels, to the gills of a fish. At a later stage these gill-clefts disappear, and the associated blood-vessels become altogether modified. If the stripes on the black kitten are its inheritance from the ancestral striped grey cat (which no one will doubt), are not the gill-clefts of the three-days-incubated chicken its inheritance from an ancestral fish, or fish-like animal? Equally striking is the case of those animals which undergo what is termed metamorphosis; which have, that is to say, an early stage, called the larval stage, which is quite different from the adult form in appearance and habits. Familiar instances of this are the frog, with its larval stage the tadpole, and the butterfly, with its larval stage the caterpillar. If we imagine the tadpole to remain closed within the egg until it was

ready to start life as a frog, we should have something in a measure comparable with the state of the chicken as just described. But it passes its fish stage in a free state; and the changes which result in the

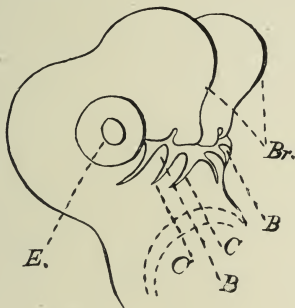


Fig. 13.—Outline of vestigial (p. 79) gills of an embryo duck incubated for five days. *E*, eye; *Br*, front of brain; *C* *C*, “visceral (or branchial) clefts,” i.e. gill-spaces; *B* *B*, parts which will afterwards join in the middle line and give rise to the lower half of the beak. (Enlarged.)

obliteration of its gills and the modification of their blood-vessels to suit the necessities of the adult stage take place while it is swimming about. The larva of the butterfly, like the larva of the frog, presents the likeness of an adult animal of a lower type; the young frog is a fish, the young butterfly is a worm. The startling changes which such animals undergo become intelligible when we confront the hypothesis that the different stages present the likeness of a progressive series of ancestral forms. In the case of the young animal enclosed within the egg, there are many other examples, besides the one already named,

in which an organ, or the rudiment of an organ, subsequently disappears gradually, or, as it is expressed in technical language, becomes atrophied. It has perhaps never attained sufficient perfection to be of any use to the owner, or it may be of such a nature as to be of no use unless the animal were adult and free. What reason can be assigned for the existence of such a structure, except that it is a feature inherited from an ancestor which, in its adult stage, possessed the complete structure and made use of it?

Then, again, there are cases in which bones, which in a lower type of animal are distinct, appear as distinct centres of ossification in the embryo of a type which has them fused into one in the adult. An instance of this appears in the *coracoid process* of the mammalian shoulder-bone. This bone, like other bones, at first consists of cartilage; and the bone-making process begins and spreads outward from an internal centre, technically called the *nucleus*. The scapula has, besides its chief nucleus, a little separate one, which eventually forms the coracoid process. Now, in the *Ornithodelphia* or *Monotremes*, the lowest members of the class *mammalia* (see p. 280), the coracoid exists as a separate bone, even in the adult. Instances of this kind are very suggestive.

It is not the force of any one instance, but the cumulative evidence of the immense number of instances, which are intelligible by the aid of a certain theory and by that theory alone, that has led em-

bryologists to formulate the law that the history of the development of the individual presents in epitome the history of the development of its kind; or, as it is expressed in technical language, that the history of the **ontogenetic** development of any form of life is an expression of its **phylogenetic** development. This formula serves as a key to a labyrinth of facts, which are all plain and intelligible with its aid; but are so far from being intelligible without its aid, that no other general explanation of them has ever been attempted. On this formula, which involves the assumption of the "Darwinian theory" in its widest application, rests the whole structure of the science of comparative embryology, to which of late years so much attention has been devoted, that it may fairly be said to constitute more than the half of zoological science.

The Science of Biology. Closely associated with the spread of "Darwinian theories" came the recognition of the fundamental unity of animal and vegetable life. The chief aids to this synthesis were the knowledge of the nature of protoplasm as the physical basis of life, a knowledge popularized in England chiefly through the writings of Professor Huxley; and the knowledge of the nature of the so-called "cell," as the essential unit equally of animal and of vegetable life, which had been already made known by Schwann. The influence of these facts may be traced in the introduction of the term *Biology*, to indicate a branch of science which treats of those general laws of life

which are common to both animal and vegetable organisms. Not only was the name new, but the study; for such general problems did not come within the scope of the zoology and botany of a previous day. The earlier naturalists had supposed that the boundaries of the two great kingdoms of organic life, like the boundaries of species, were arbitrary and fixed. The forms that presented links between the two were looked upon almost as monstrosities; nor were the types usually adduced as links always those most fitted to serve as such. The form was noted, rather than the structure; and the likeness between plants and animals was illustrated by reference to animals such as the sea-anemone, and other so-called *Zoophytes*, which present no resemblance to vegetable forms except in the radial symmetry which is the necessary result of their fixed position (see Chap. VI.), or in the multipartite arrangement of their colonial forms. But the resemblances brought to light by the investigators of the present century are fundamental and comprehensive; indeed, so intimately connected are the two great groups of living things that a knowledge of the one would be incomplete without some reference to the other, as has already been shown in the earlier chapters of this little volume. The "Darwinian theories," it will easily be understood, are not less closely incorporated with the science of Biology than with the science of Embryology.

Since the introduction of the theories of Darwin, the general ideas which are indicated by the terms

“evolution” and “development” have been elaborated by other thinkers, whose province was less specially that of natural history and more decidedly that of abstract philosophy. We owe to Mr. Herbert Spencer a clear explanation of their underlying idea as being that of the progress of **differentiation**, or change from the *homologous* to the *heterogeneous*: a process of growth, that is, by which a simple form gradually initiates the structural details of a complex form. All this is included in our ordinary idea of growth. When we think, for instance, of the growth of a plant—I instance a plant because the progress of its growth is more familiar and accessible to our observation than that of animal forms—we do not think merely of its increase in size, but also of the mysterious though familiar processes that go on concomitantly with the increase in size; the processes by which the seedling, with its simple structure of a straight stem and a few pairs of leaves, presently opens out into a complicated system of countless branches of which the seed held no trace; the processes by which the soft indefinite tissue of the growing point of a stem stiffens into new and varied forms of tissue that build up leaf and flower; the processes by which the flower, losing a certain set of tissues and organs, gives rise to others wholly different, and alters into the fruit, cradle of new organisms destined to pass again through the same cycle of successive change. These processes, which are not merely the unfolding of what was already there, but the production of

something new that was not already there, except in a potential sense, constitute the "development," the "differentiation," the "ontogeny," of that individual plant. These changes are crowded into a short period; we mark their progress in the springtime, day by day, almost hour by hour. But those slow changes, which constitute the growth not of individuals, but of races, kinds, and classes, have, for the measure of their long hours, not the gradations that mark the passage of the shadow on the sundial, but the rise or wreck of continents and the secular displacement of the poles. To us, the creatures of a day, they can only be made apparent through the insight of the mind—of such a mind as Darwin's, which by its patient inductions linked the isolated facts given us by the evidence of the senses into a bridge that oversteps the bounds of time. To that insight of the mind, the short familiar work of growth is the witness of its larger cycle; and each tiny germ of life holds, waiting to be read, the secret of the whole universe, and the long history of the organic world.

Now that we have gained an insight into the processes by which the different forms of life have been developed, it becomes evident that we have before us an inexhaustible field of discovery. Those processes are still going on, and by careful observation we may hope to see species in the making, to watch the development of new kinds. It would be impossible to discuss here the various controversies that have arisen as to the causes that lead to what Darwin called varia-

tion. But it may be stated, in general terms, that the outward circumstances which surround an animal, sometimes spoken of as its "environment," may produce variations as well as select them. The study of the correlation of slight differences in the structure of any kind of animal with slight differences in the climate, soil, and other characters of the various districts in which it is found, may be expected to afford us much further knowledge. Evolution is still at work; and the student of evolution finds in the history of the past a suggestion of the story of the future. We have reason to believe that, so far, the latest products of the evolution of animal life have been, broadly speaking, the best—the most complex in structure, the most intelligent in mind; and therefore we may reasonably suppose that the future still holds the best of nature's work in store. The world of the future will contain new and beautiful forms of animal life which we have not seen.

The life of human beings, too, is governed by the same laws as the world of animal life; it is a story of upward progress, urged on by hardship and the struggle for existence, towards the attainment of a nobler type. The working of evolution has produced citizens instead of barbarians; it has made artists and musicians, surgeons, mathematicians and engineers, out of the descendants of savages and cave-men. We have many indications that our race has not yet attained its maximum of power; its future will surpass its present, even as its present surpasses its past.

Poets have pretended that the golden age of the world is over: the evolutionist sees that it is yet to come.

NOTE.—The student should guard against too hasty acceptance of post-Darwinian teachings regarding evolution and development. The best summary of recent ideas on these subjects will be found in the pages of Thomson's "Outlines of Zoology."

CHAPTER V.

EMBRYOLOGY AND REPRODUCTION.

THE faculty of reproducing from an egg or germ the facsimile of themselves is the most striking characteristic of living objects, as distinct from objects not possessed of life. Where an animal or plant consists of one cell only, it is obvious that the growth of a new cell, if perfectly similar to the first one, is reproduction, so that in such cases it is often, though by no means always, not possible to distinguish a special reproductive process. But in multicellular plants and animals, special cells are told off for the work of reproduction, and modified accordingly, as is the case with every other vital process or function. These cells and their functions may best be understood by referring to the facts observed in certain unicellular organisms. Two unicellular individuals, alike except in size, or nearly so, touch one another and fuse, their soft protoplasmic substance running together; their two nuclei fuse to form one nucleus, and their outlines become rounded off, so that they form one cell. This process, the union of two similar cells, is called conjugation (Fig. 21): it is comparable with the reproductive process in certain plants, viz., two orders of

the algæ, the *Conjugatæ* and *Zoosporeæ*.¹ The cell, so formed by union of two cells, may now become *encysted*; that is to say, the soft protoplasm forms a hard wall round itself, and becomes round and motionless for a long time. This stage of *encystment*, again, is very like a form assumed by the cells resulting from conjugation in certain vegetable cells,² which get a special hard coat, and remain dormant for a long time, and are thus enabled to resist the results of dry weather or other accident; resting cells of this kind are called resting spores, spore being the name given to the reproductive cells of the lower vegetable forms. After a time the encysted form again becomes active, breaks through its hard shell or cyst, and leaves it behind. It will next divide into two or more new cells. We have here the simplest type of sexual reproduction. In *Vorticella*, the two cells that unite are slightly different from one another; one is larger, and is borne on a stalk; the other is without a stalk, and swims freely. Here we have an indication of the differences between male and female, the free and more active cell representing the male.

In multicellular animals, as we have already said, there are special reproductive cells, contained in special reproductive organs of a more or less com-

¹ See Prantl and Vines' "Text-book of Botany," chapter on the *Thallophyta*.

² *Zoosporeæ*.

plex kind. The type of these is always the same, the male cell being an active moving cell (somewhat resembling the flagellate infusoriæ in form), while the female cell, called the egg-cell, or germ-



Fig. 14. — Spermatozoa of Medusa and of Frog. (From Claus and Sedgwick.)

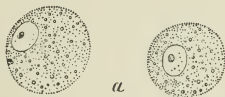


Fig. 15. — Ova of a Medusa, showing large nucleus, with nucleolus. (From Claus and Sedgwick.)

cell, or ovum, is a round cell somewhat resembling the encysted cell already described, and distinguished by a specially large nucleus, with a distinct nucleolus. The nucleus of the unfertilized egg-cell is sometimes spoken of as the pronucleus. The sperm-cells are developed from cells formed by the division of large cells which look like young ova, and are called “mother cells” of the sperm-cells in all but the simplest animals. The germ-cells and sperm-cells are contained in distinct organs called respectively the ovary and the testis, and furnished with efferent ducts, the *oviduct* and *vas deferens* respectively. Many of the invertebrata present a structure comparable with that of most flowers, the male and female organs being both present together; but

in the higher animals this structure is not retained: one kind of organ only, either male or female, is developed in one individual. In this case, the individuals become different in appearance, and the male develops some distinctive character, as in the familiar case of the cock, with its fine plumage, or the lion, with its long mane. They also become different in character, the female, devoted to the care of her offspring, being gentle and peaceable, while the male, who has usually to win his mate by fighting the other males, is combative and fierce. This is the general rule; but there are some curious exceptions, in which, owing to some unusual mode of life on the part of the species, the female is stronger, or fiercer, or larger, than the male. It may as a rule be stated, that the male animals of any class differ more from those of allied species than the females do from the females of allied species; in other words, the female usually shows us the *normal*, or usual, the male an *aberrant* or unusual type. Next to continuing its own life by eating, the most important function of any animal is to continue the race; the sexual organs are therefore all-important parts of the animal structure, and classification is very largely based on their resemblances or variations.

As has been already mentioned, some of the unicellular organisms are able to reproduce themselves by division, without any sexual process. The lower forms of animal life nearly all do the same, while they also reproduce themselves sexually. The asexual reproduction is called "budding," because the new

animal grows gradually out of the other, like a bud out of a stem. In many forms there is an alternate occurrence of sexual and asexual reproduction, producing what is known as alternation of generations (see p. 150). The asexual mode of development does not occur among the higher animals; but among the insects there is a variation of it called *parthenogenesis*, in which new individuals are produced from germs which are very like ova in appearance, but do not require to be fertilized. It is believed that the essential difference between true egg-cells and these is that the former cast off certain small bodies formed from portions of the protoplasm of the nucleus, and called *polar bodies*. It is believed that in this way the ova lose the power of growing on their own account, and become dependent for further development on the stock of energy which is contributed to them by the male cell which they absorb. True ova cast off two polar bodies. The asexual germs above spoken of (*pseudova*, or false egg-cells), which occur in the common Green-fly or Plant-louse (*Aphis*), form but one polar body; instead of casting off this, they retain it within themselves.

The egg-cell, which, as already stated, is a round cell with a particularly large nucleus and nucleolus, is fertilized by the male cell, which fuses with it much as the free *Vorticella* fuses with the fixed one, only that the discrepancy in size is greater. The egg-cell then begins to divide by two, and again by two several times, until a bunch of cells is formed. This process

is called **Segmentation**; the product is called the **Morula**, or mulberry stage, because it is like a mulberry in shape. It has been shown comparatively lately, that each of the "segments" of the morula is an amœbiform cell, connected with the others by means of pseudopodia. In order to express



Fig. 16.—Developing ovum of a starfish: *a*, with four segments; *b*, with eight.—(From Claus and Sedgwick, after A. Agassiz.)

this interconnection of the cells, the name **Syncytium** has therefore been given to this stage. It is believed that the cells and tissues in adult animals are for the most part similarly connected. Very frequently a round ball, hollow in the middle, is formed instead of a round bunch, the cells forming a thin layer round the hollow. This is called the **Blastosphere** or **Blastula**.

The next stage is called the **Gastrula**, or Stomach-animal; it is formed by the flattening and curving in of one end of the sphere, until there is a little bag inside the sphere at that end. The little bag represents the primitive stomach; it is called the **Archenteron**, or primitive internal cavity: the mouth which leads to it is believed to represent the primitive

mouth; it is called the **Blastopore**. The outside is the skin layer or epiblast, of which we spoke in Chapter III., the inside is the stomach layer, or hypoblast, and

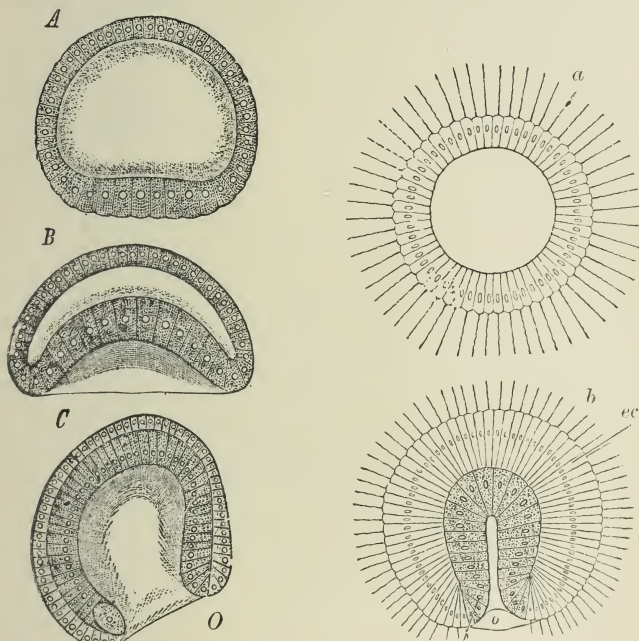


Fig. 17.—*A*, Blastosphere (of *Amphioxus*); *B*, beginning of the formation of Gastrula, by invagination of the endoderm; *C*, complete Gastrula.—(From Claus and Sedgwick, after Hatschek.)

Fig. 18.—*a*, Blastosphere; *b*, Gastrula stage of a jelly-fish (*Aurelia aurita*); *ec*, Ectoderm; *o*, Blastopore or mouth of gastrula.—(From Claus and Sedgwick.)

the middle layer is not developed at this early stage. Sometimes this blastopore becomes the mouth of the adult animal; sometimes, in higher forms, it undergoes

alteration and becomes, on the contrary, the excretory opening, or anus; and sometimes it disappears, while a new mouth and anus arise. The Gastrula is usually formed by invagination¹ in the manner described, but not always.

The Morula and Gastrula stages are believed to represent the stages passed through by the animal's ancestors; first a multicellular stage with cells all alike, then a free-swimming animal with a mouth and stomach. The two-layered Gastrula may be compared in structure to a Hydra (page 130, and Fig. 11, page 46) without tentacles.

The Gastrula stage consists of the two primary body layers. At a later stage the mesoblast is formed, consisting of amœboid cells (Fig. 10). It is derived from the primary layers, but by processes which are not the same in all cases. The lymph corpuscles, or white corpuscles of the blood, may be considered to represent the original type of mesoblast cell, very like a free *amœba*. Cells of this type compose the bulk of the mesoblast in many of the lower invertebrata, and in prepared and coloured sections of the animals are seen as cells with long processes; in the living animal these processes are capable of some movement. In the lower forms of animal life the animal stops at this state of development, the epiblast and hypoblast remain-

¹ Invagination (from Lat. *vagina*, a sheath or hollow case) is the term applied to the formation of a structure arising in this manner as a fold in a previously continuous wall of tissue.

ing as simple uninterrupted layers, and the mesoblast cells remaining stellate : in that case, the epiblast is

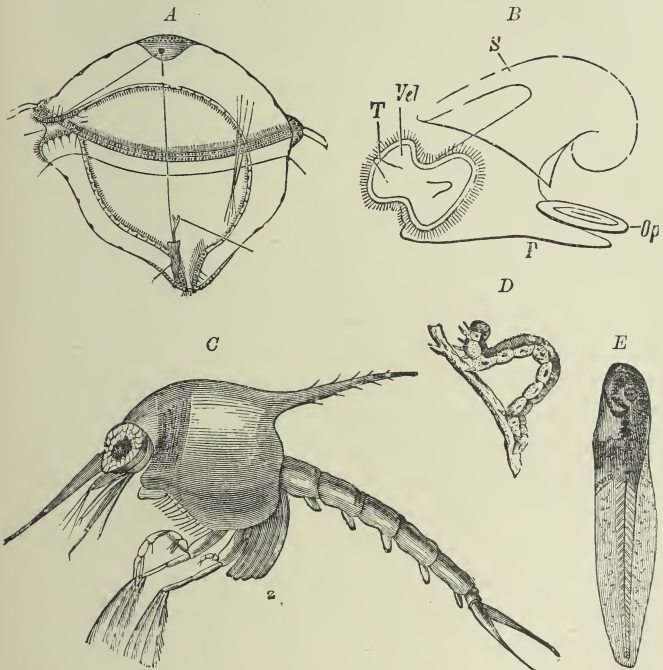


Fig. 19.—A group of larval forms: *A*, Trochosphere, or larval stage of a worm; *B*, Veliger, or larval stage of a mollusc; *C*, Zoea, or larval stage of a crab; *D*, Caterpillar ("looper"), or larval stage of a moth; *E*, Tadpole, or larval stage of a frog. *D* is of natural size, *E* slightly enlarged, and the others are represented as considerably magnified.

known as **ectoderm**, the hypoblast as **endoderm**, while the mesoblast is called **mesoderm**. In some cases the middle layer is called **mesenchyme**, by

way of providing for the uncertainty which exists as to whether, in these cases, it is altogether comparable with the mesoblast of other types. Animals develop to a higher point, in which the body layers develop complicated organs, usually go through a larval stage very different in appearance from the adult.

When an animal leaves the egg in a form fairly similar to that of the adult, it is said to develop *directly*; when it is of an entirely different shape and appearance, and has to lose some of its parts, or gain others, before it grows up, it is said to undergo **metamorphosis** or change of form, and the early stage is spoken of as the **larva**. The development of the butterfly is the most familiar instance of this; it changes twice, from the worm stage or caterpillar to a resting stage, called the **pupa**, whence issues the **imago**, or perfect insect. Most larvæ, however, do not present a pupa stage. The vast majority of the invertebrata undergo metamorphosis; it is only among the vertebrata that we find direct development the rule; but even there the Amphibia, which have a larval stage, are an exception. Animals with direct development may, however, be more correctly described as undergoing metamorphosis within the egg, than as having no metamorphosis; for great and startling changes in their structure take place within the egg, although these are not so strikingly apparent to the observer as when there is a free larval stage. The young animal enclosed within an egg (or, in mammals, before birth) is called the **Embryo**.

An egg, it will be remembered, usually contains yolk, which supplies food to the growing animal. The stages spoken of above on page 70 are described without reference to the yolk. When much yolk exists, the embryo which corresponds to the gastrula may be considerably modified. In the hen's egg, for instance, it lies flat upon the yolk, so that its component layers are nearly parallel, the top layer representing the outside layer of the bag-like gastrula, while the lower layer, which rests upon the yolk, represents the inner layer of the gastrula (hypoblast). Eggs which have little or no yolk are called **Holoblastic**, because the whole of the egg takes a direct part in the formation of the embryo, and eggs with much yolk are called **Meroblastic**, because only part does so. It is so easy to procure hen's eggs, and watch their different stages of development, that the student of egg development is always introduced to "the chick" for a first lesson. The outside of the egg demands a little attention. The protective shell of the egg consists of carbonate of lime; if the hens are not supplied with food that contains plenty of this, they will lay eggs with soft shells. The white serves more than one purpose: not only is it absorbed by the chick, but it acts as a cushion to keep it from being killed by knocking against the shell, if the egg is jarred in its early stages. The germ, or embryo, lies like a flat cake on the top of the yolk. When it is cut through in a direction perpendicular to its flat extension, in slices thin enough to be examined under the micro-

scope, the thin embryonic layers already spoken of are seen one below another (Fig. 23). In the middle is seen a round body which is a section of a hollow tube; in very early stages this round body is seen to be formed at first as a long median fold of the outside layer, from which it is afterwards constricted off, so as to

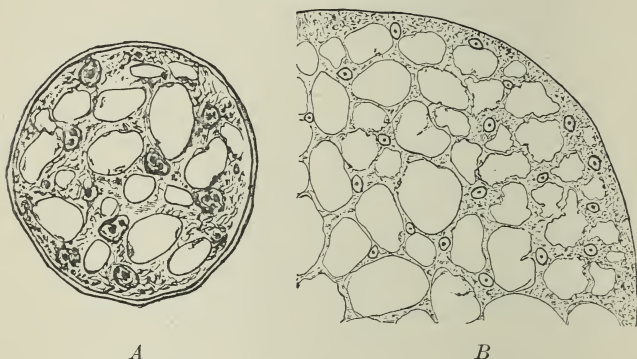


Fig. 20.—Notochord (highly magnified) of embryo duck in transverse section. *A*, duck of four days' incubation; the cells have large oval nuclei, often containing two nucleoli (p. 20), and contain large vacuoles (p. 22). *B*, duck of six days' incubation; the vacuoles are much larger, so that the cells are reduced to mere threads lying between them. (For position of notochord see Fig. 23, p. 113.)

form a closed tube lying inside (Fig. 24). This closed tube afterwards becomes the brain and spinal cord, or central nervous system of the body, the bony protection of which we call the skull and spine. The fact that the spinal cord is thus formed shows us that the nerve tissues are formed by modification of the skin layer. (See Chap. III.) Underneath this spinal cord

lies a solid rod of cells (Fig. 23), derived from the hypoblast, which is called the **notochord** (string down the back). In the higher vertebrates it only exists in the embryo; when bones begin to be formed round the spinal cord, it is merged in them and lost. It is found in a kind of creature very different from a bird, the *Ascidian* (Leather-bottle animal), or Sea Squirt, (Fig. 84), a marine animal which is found fixed upon stones and shells. This animal, like a butterfly, has a larval stage which is different from the grown-up stage. The larval stage has a long tail, which, like the tadpole's tail, sinks in and disappears as the animal grows up. Now, in this tail is found a *notochord* like that in the chick. It appears not only in the chick, but in all other back-boned animals, at a similar early stage; and the lower we go in the scale of back-boned animals, the larger we find the notochord, and the longer it persists. In the *Amphioxus*, which is the lowest of the series, and only by courtesy called a back-boned animal at all, it is large, and persists in the adult; the same is the case in some fishes. When the coincidence of structure between the vertebrate and the ascidian embryo was first noticed, great excitement was created in the scientific world; and it was thought that we were following up a clue to the answer of the interesting question "From what invertebrate type are the vertebrates descended?" It was popularly supposed that scientists traced the pedigree of man directly from the Sea Squirt, an impression that

gave rise at the time to a good deal of harmless fun, when a clever parody on a well-known song traced the drinking propensities of the human subject to its descent from "the Leather Bottel." But we now recognise clearly that the ascidian and the vertebrate can only be collateral offshoots from some parent form, now lost, or as yet undiscovered in the depths of the sea.

A word should be said here as to the present state of knowledge regarding links between the vertebrates and invertebrates. If we hear less about the Ascidian than formerly, it is not that it is now deemed less really important. It is almost impossible for us now to realize the change made by the discovery of a link which connected the vertebrates with lower forms.

The notochord is also found in a link which has attracted more recent attention, a worm-like marine animal called *Balanoglossus*. It has a larval stage which resembles that of the Sea-urchin; and when grown up, it has a row of gills to breathe through, which strongly remind one of the breathing apparatus of ascidians (Fig. 86, page 238).

But it is not only by the discovery of new forms that we get light on the relationships of the back-boned animals, but quite as much by the careful examination and reconsideration of forms already known. If there is one thing we consider more distinctly characteristic of the back-boned animals than anything else, it is their possession of paired eyes and ears; but it was announced a few years ago

that some of the Reptiles are possessed of a third eye, median in position. The discovery of a fabled Cyclops, a veritable giant with an eye in the middle of his forehead, would hardly have been more startling. Yet the rudimentary¹ structure to which this interpretation has now beyond doubt been assigned, called the *pineal gland*, has been known to anatomists for centuries: its use has always been doubtful, and we owe to Descartes the suggestion that in the human being it was the seat of the soul! In certain reptiles it clearly shows a structure corresponding to that of a rudimentary eye.

The description of the longitudinal structure in the early chick, called the notochord, led us to consider the links between vertebrates and invertebrates: the egg itself, as a structure, serves as a reminder that there are links, equally interesting, between the highest group of the vertebrata, the mammalia, and the other classes. The absence of eggs, on account of the production of the young by birth instead of by hatching, has always been noted as the great characteristic of the mammalia, although there are exceptional instances of viviparous species in many groups of animals. But in 1884, the lowest members of the mammalian group, the *Ornithodelphia*, were dis-

¹ When an imperfect structure appears to be the inherited trace of an ancestral structure which was complete and perfect, it is often spoken of as vestigial (from Lat. *vestigium*, footprint or trace) rather than rudimentary. The latter word is retained above, as more familiar to the general reader.

covered by Mr. Caldwell to be animals that produce eggs provided with a yolk. In these animals, which in other respects present a number of characters linking them with the lower vertebrates, we have therefore a direct link between egg-laying or oviparous animals and viviparous animals.



A.



B.

Fig. 21.—The process of conjugation between similar cells. *A*, in *Spirogyra*, a plant belonging to the Algæ; *B*, in an Infusorian. *A*, slightly, *B*, considerably magnified. See page 63.

CHAPTER VI.

THE SYMMETRY OF ANIMAL FORMS.

THE determining condition of animal symmetry is the power of movement, which renders the vast majority of animal forms the possessors of bilateral symmetry. That is to say, animals usually consist of two similar halves arranged right and left of an axis. This axis is the direction of forward movement: the end of the axis that moves forward is the head, the end that follows is the tail; by reference to which, respectively, we distinguish the succession of intermediate parts as comparatively anterior or posterior. One surface progresses along the surface traversed, and one is turned to the sky: the former is the ventral or belly surface, the latter, the dorsal or back surface. There are a few animals, including the human, in which these terms are slightly modified in meaning, because the animal has an upright posture; but they still refer equally correctly to the arrangement of its parts. It is very easy to understand how animals formed in this way obtain the idea of space in three dimensions, which seems to us at first sight the only way of measuring space, though other ideas might occur to animals built on a different plan.

Animals which have not the power of moving from place to place are often possessed of a radial symmetry, consisting of similar parts arranged with reference to a centre, like those of a flower. The radial symmetry, is in fact the expression of a fixed position: the whole symmetry of the majority of plants is essentially radial, though mostly modified into a spiral type by the successive development of their parts in chronological order: while the occurrence of a bilateral symmetry in them is usually traceable to mechanical conditions, such as reference to surfaces affording support or moisture, aptitude for undulation under the action of wind or water, or adaptation to the entrance of insect visitors.

There are animals which are free but float rather than propel themselves, which, like the fixed ones, also present a radial symmetry: both usually belong to the group called *Cœlenterata*. The same group presents some interesting links between radial and bilateral symmetry among some of its more active free-swimming forms. A curious instance of a partial radial symmetry is presented by some of the *Echinodermata*, for example, the Star-fishes, which in their larval stages are free-swimming and bilateral, and in their adult stages, though unfixed, move in any direction indifferently; the axis of their vertical height approximately represents the longitudinal axis of other animals, so that they move sideways. The Sea-urchins, nearly allied to them, present several curious intermediate types of symmetry.

A large number of animals have a peculiar kind of symmetry, consisting in the repetition along the longitudinal axis of parts or joints that are almost exactly similar. These similar parts are called **Segments** or **Metameres**; and an animal possessing this kind of structure is called a **Segmented animal**. Familiar examples of segmented animals are the earth-worm, with successive rings; the centipede, the caterpillar, or the lobster, with successive rings which bear legs. An animal with a row of pairs of legs, like the lobster



Fig. 22.—A segmented animal, belonging to the Crustacea, the Opossum Shrimp, *Mysis vulgaris*. The body has successive metameres, or joints, and pairs of appendages.

or centipede, usually has some of them modified in some way to serve various purposes other than that of walking: thus, some of the lobster's legs carry gills to breathe with; some walk, and some nip. Legs of this kind are referred to as **appendages**, a term that covers all movable structures attached to a body-ring, whatever their special use.

Many animals that have not an obvious metameric structure bear traces of it in some of their organs. Thus a fish exhibits a segmented type by its rows of successive masses of muscles; and indeed all the vertebrates show something of the kind in the succes-

sive joints of their back-bones and successive pairs of nerves branching from the central nervous axis.

How this kind of symmetry first arose is quite uncertain ; but it is the predominating type of the animal kingdom, intimately correlated with the power of moving from place to place ; while the radial symmetry is a restricted and therefore comparatively unimportant type, and the bilateral type, without any trace of metamerism, is almost confined to the lower groups of worms.

Something has already been said about the **limbs** of animals, which, in the case of typical segmented animals, are called appendages. The majority of animals have limbs of some kind. Unicellular animals, such as *amœba*, put out temporary branches of their protoplasmic substance, to catch or feel with, and hence cells which can do so are called *amœbiform*. These branches are called **pseudopodia**, or false feet. Others of the *Protozoa* have long feelers of protoplasm, which are fixed in shape. The *Cœlenterata* have **tentacles**, or feelers, fleshy arms surrounding the mouth on all sides, which give them their radiate appearance, and are often endowed with special stinging cells, which paralyse the prey they catch. The higher segmented animals present an amazing variety of limbs, as in the case of the lobster already mentioned, or the typical insect. The latter has three pairs of walking legs, and *antennæ* or feelers on the head, besides movable jaws.

In speaking of the limbs or appendages of an animal,

we speak of the attached end as the **proximal**, or near end, and of the free end as the **distal**, or far end. The limbs of vertebrates are provided, like their bodies, with supporting structures called bones. In the lowest vertebrates, the fishes, the limbs divide at the ends into a number of bony rays; these are called fin-rays. Many fishes have also a median,¹ or middle, fin, along some part of the middle line of the body.

In the higher vertebrates the fin-rays are usually represented by digits, that is to say, fingers and toes, larger in size than the fin-rays of the fish, and usually protected by a hard dermal tip at the end forming a nail or claw. But they are subject to great modifications.

The Tail.—From the median fin-ridge of fishes, which gives rise to the median fin just referred to, are also formed the fins of the tail—the most important fins of all, with which the fish not only propels but steers itself. The lobster's tail, of four loose flaps, should be noticed by the student, and compared and contrasted with that of the fish.

The tail is not always developed; and when it is, it is often merely as an ornament. But to the birds it is nearly as useful as to the fishes; and in monkeys, and other animals of arboreal habits, it is often prehensile, and used in climbing. Among English animals, the little harvest mouse is the only one that can use its tail in this way. The tail does not ap-

¹ This is usually spoken of as the Azygous, or unpaired fin.

pear to have any specially prehensile character; but it has been seen to use the tail in this way, and since the mouse often builds its nest in the stalks of corn, it is easily understood that its climbing powers will thus be greatly assisted. Doubtless the long tails of the mice and rats are put to all sorts of uses; it is on record that rats have been seen to put their tails down the neck of a bottle of oil, and then lick the oil off; and from this we can understand how easily a mouse can turn its tail to prehensile uses, when there is anything to be gained by doing so.

The Head.—I forget who it was that first defined the human being as “a stomach with appendages”; it was an apt description of animal life in any form high enough to possess a stomach. The head may, with about as much justice, be defined as a *mouth* with appendages. The mouth is well at the front of the head; but still more in front (pre-oral) is usually a nose, in some form or other (perhaps very rudimentary, as in *Amphioxus*), to smell whatever presents itself, and judge whether it is fit for the mouth to eat. In insects and crustaceans, the power of smelling is vested in the antennæ, or feelers. The eyes are there to see anything at a distance that may be eatable. The ears are useful rather to warn of the approach of something that may eat the owner, than of the approach of something that may be eaten, and the eyes and nose take their share of this office also.

The mouth itself is a single organ. It is worth while to remark, that the plan of bilateral symmetry

includes single organs placed on the median or middle line. These are often spoken of as "unpaired," but it must be remembered, that they are alike on both sides. The median eye (spoken of on p. 79) and the median fin (p. 85) may be noted as instances of "unpaired" structures. More familiar instances are the cock's comb and the horse's mane.

But the distinguishing feature of the head is the presence of the **brain**, that central part of the nervous system which correlates the impact of feeling from without with the impulse of action from within, and is the physical seat of those synthetic mental powers of the organism as a whole which, viewed from their subjective side, we call **consciousness** and **intelligence**. The brain reaches its highest development in the vertebrata, and among these its culmination is found in man. The peculiarity of the brain in vertebrates is, that it is all placed above the mouth. In most segmented invertebrates, including some of very high intelligence, such as the lobster, the brain is supplemented by nerves which form a collar passing round the mouth and throat.

CHAPTER VII.

THE DISTRIBUTION OF ANIMAL LIFE.

IN order to appreciate the force of the Darwinian theories, a clear appreciation of the effect of geographical conditions upon animal life is very necessary. The effect of the present distribution of land and sea is easily understood. Terrestrial animals cannot pass a wide stretch of ocean, nor aquatic animals pass a barrier of land ; and isolated lands or isolated seas are therefore apt to present peculiar types. These types are often *archaic*, or old-fashioned ; that is to say, they present features which, on the Darwinian hypothesis, we should suppose to mark them as *older* kinds, belonging to a past age, and resembling those of extinct animals represented now only by remains existing in geological strata. These types are not so highly specialized ; that is to say, some of their organs present a form which we may easily suppose to be the beginning of those organs as they exist in other and more familiar types, but without all the latest improvements which these other and more familiar types possess. The archaic types of animal, in short, present in their build the same relationship to the more widely distributed types that the first locomotive or the first sewing-machine presents to those

now in use. They suggest forcibly that they belong to a past period of time, when the latest patents in anatomical structure had not yet been taken out by nature's "'prentice hand." Instances of such types are found in the marsupial animals of the Australian region, which present the lowest form of the true mammalian type.

The reason why old-fashioned types persist in isolated lands and seas is believed to be because in these places the struggle for existence is not quite so keen. In a large area, the strongest types, which become developed in any part of it, quickly make their way to every other part; and naturally the kinds with what I call the last patent improvements in structure will soon crowd out the old-fashioned kinds. In the isolated places such new intruders from other parts cannot enter, and so the old-fashioned inhabitants get a chance to survive. But if, by accident or artificial means, animals from the mainland are introduced on an island, it is usually found that they are so much stronger, that they spread with surprising rapidity, and drive the aboriginal kinds away, these latter being weaker, because, as already said, they have been bred in a place where the struggle for existence is not so keen. An instance of this sort is the recent spread of the rabbit in Australia. At home, in Europe, the rabbits are kept in check by weasels and other carnivora; but in Australia there are only sham carnivora—marsupial animals modified by carnivorous habits, often weaker than the true carnivora—and not very

numerous, many of them having been destroyed by man. So the rabbits are not checked, and their natural advantage, that of breeding very rapidly, enables them to over-run the place and crowd out the animals that preceded them. Similarly in England the introduction of the European grey rat resulted in its spreading very rapidly, and driving out the English black rat, which was reduced in number. Another curious instance of the same thing is the history of the Manx cat. This by no means pretty variety of the "harmless necessary" pussy is believed to have been introduced from Spain, where a similar variety is said to be found,¹ by a ship of the Spanish Armada, which was wrecked on the south coast of the Isle of Man, giving a name to a cliff which is still called Spanish Head. It afterwards spread over the whole island, besides supplying innumerable emigrants, which may be found in the possession of cat fanciers in many parts of England, especially among the northern counties. So prevalent did the tailless cat become, that the Manx people began within recent years to import tailed cats from England as a change. The tailless variety, established as an insular race, was now not so strong as the ordinary sort imported from the larger island, and therefore the tailless cats are now becoming rare again,

¹ A variety of tailless cats is said to exist also in Japan. Whether the disappearance of the tail is due to inherited mutilation, to a correlation with the peculiar gait of the animal, or to a merely accidental variation, is uncertain.

their characteristic being lost by interbreeding with the imported cats. The variety has some curious points, its peculiarities being not limited to the absence of tail. It is exceptionally savage, and the hind legs are often unusually long, giving it a hopping gait so like a rabbit's that local naturalists, innocent of zoology, and vague in their ideas about nature's possibilities, have been known to class the creature as a hybrid between the cat and the rabbit. Local tradition states that the Spanish cats were of that pale sandy colour, not very common among English cats, which is sometimes called Judas colour, as the nearest approach to red hair that cats can manage. This colour, at any rate, is now among the commonest colours of the island cats, both as an all-over colour, and in patches, and both with and without the accompaniment of a tail. It is worth while remarking, that the ship from the Armada contributed additions also to the human inhabitants of the island, some of whose descendants still preserve their pedigree. Such immigrants, wrecked on an island where the people were ignorant of maritime arts, might have supplanted the aborigines, like the cats; but a seafaring people, for obvious reasons, do not share the weakness of island races, and can hold their ground against all intruders, or even, as in the case of the English nation, maintain their own, and also possess themselves of what is not their own, on foreign ground.

But in considering the distribution of animals, we have to consider not only the effect of the existing

distribution of land and sea, but also of the distribution of land and sea in past ages, so far as it can be ascertained. Two islands may exist at a long distance from another, the animals inhabiting which are the same; yet two other islands comparatively near to one another may differ remarkably from one another in their inhabitants. Such cases may respectively have arisen where islands are the last relics of a sunken continent, which formerly connected them, or where the separating sea-line has been long unchanged.

The various kinds of animals which inhabit any region are referred to collectively as its **fauna**, in the same way as the vegetable forms of life are referred to collectively as its **flora**. The term is a convenient one, because its use serves to remind us that the different types of animal included under it have been moulded by similar causes, and have interacted on each other in a way that makes a knowledge of the whole set necessary for a thorough understanding of the habits and circumstances of any one.

Still more interesting than the geographical distribution of animals is their distribution in time; but this is so complicated a subject that it constitutes a special science, to which is given the name of **Palæontology**.

Probably every one now possesses a moderately clear idea of the conditions under which the fossil remains of animals have been preserved. The rocks which contain fossils are those which are called

stratified rocks, because they are laid down layer after layer, or aqueous rocks, because they are formed under the agency of water. The action of the weather continually wears away, or, in the phrase of the geologist, denudes, the surface of all land or rock that lies exposed to the air; and the bits thus removed, often so fine as to be imperceptible, are washed away by rain, and carried down to the sea by rivers, and finally deposited in layers at the bottom of the sea, the layers consisting of shingle, sand, or mud, according to the fineness to which the particles have been ground down during their removal and transit. The dead remains of animal and vegetable forms sink and get mixed with these deposits; or, when the deposit is laid down deep in the ocean, far from the land and the silt that rivers bring down from it, the deposit may even consist almost entirely of organic remains. The majority of fossiliferous rocks are formed in this way, the cases in which local causes give rise to the formation of local deposits in places above the level of the sea being comparatively rare.

Following out the logical consequences of the Darwinian theories, we should expect to find in the oldest rocks remains only of the simplest animals, and to meet with a gradually ascending series, in which the more highly organized animals appeared gradually. Practically this is what we do find. But the geological record is for many reasons very imperfect. The most obvious of these reasons is, that new stratified rocks are not formed all over the globe,

but only by the agency of water; they therefore can only represent the inhabitants of *the land* by a chance fragmentary specimen; nor is it likely that rocks of any age completely represent the climatic regions even of the faunas of the seas. Again, the stratified rocks of one age are constantly being destroyed by the denudation of a subsequent period. Not only so, but when we consider that all our quarrying and exploring is but an infinitely insignificant process of nibbling at the edges of the huge fields of rock which contain the buried record of past ages of life, it must be obvious that much remains for future workers to discover. From the imperfect record of the past that we have at our command, we cannot therefore hope to get the story of the development of life arranged in a neat set of consecutive chapters, like the novelette that runs through the successive pages of a popular magazine. But allowing for the necessary imperfection of the record, we do get a series of fossil forms presented by the ascending series of rocks, that bears ample evidence to the general truth of the Darwinian views.¹

It must be clearly borne in mind that the development of new and more highly organized forms does not by any means imply the extinction of the simpler type from which they have been derived. We have

¹ Thus, *e.g.*, fishes are found to precede reptiles in the geological record, while reptiles again precede birds and mammals.

the simplest unicellular animals still existing side by side with the highest forms of life; in the geological record we may expect therefore to find evidence of a similar state of things; nor have we any reason to suppose that the earliest fossiliferous rocks we are acquainted with are the product of a period of time in which only very simple forms existed. It is probable that the rocks which contained the record of the earliest developments of life have long been converted into what are called *metamorphic* rocks—rocks which, while they preserve traces of their stratified origin, have been so altered in their intimate structure by heat, pressure, and chemical action, that the organic remains they formerly contained have all been destroyed. Stratified rocks are constantly being altered in this way; and the older they are, the less is the chance that they will have remained unaltered. Moreover, it must be remembered that only animals that possessed some hard structure are preserved in a fossil state. The *foraminifer*, with its shell, lasts almost for ever; but of cells like the *ameba*, no trace could remain embedded in a rock. It is therefore vain to hope to trace the earliest history of life from the record of the rocks, although we find in them the landmarks of its subsequent development.

But since the simpler types survive still, the interesting inquiry presents itself whether we may not be able to discover life in the very making, find the simplest type of all, and see whether its cells are really always produced from a pre-existing germ of

life, or whether they are in some mysterious way developed from the material of inorganic nature. This last theory,—namely that of the *spontaneous generation* of life,—has been held by some inquirers; but their best efforts have not sufficed to prove that it has any ground at all. The organisms whose insidious presence manifests itself in solutions which the experimenter has believed to be clear of all traces of life, and secured from the entrance of any, are organisms closely allied to the germs which modern research has shown to play so important a part in the history of many diseases and septic conditions. On account of their extreme minuteness the study of these forms is attended by great difficulties, and, for the same reason, their growth may sometimes seem to be spontaneous. Yet it may safely be said that it is at least as likely that they present a type already highly specialized and of a retrograde character, as that their apparent simplicity is that of a primitive type, such as we might expect life in its first beginnings to present. History repeats itself; and probably those who have looked among these “germs” for the initial form of the living organism have made the same mistake as those who looked to the Ascidians, —a highly specialized though perhaps retrograde type, —for the initial form of the vertebrate organism.

Whatever may be the outcome of further research, it must at present be said that we know nothing whatever regarding the *origin* of life. So far as we know, all living forms take their origin from previously

existing living forms; and all speculations hitherto made upon the subject of the inter-relationship of the lowest forms of animal life leave us much in the position of the owl described in one of Mr. Froude's essays, who spent his life in sublime meditation on the (to him) insoluble problem, "Whether in the Beginning the Owl first came from the Egg, or the Egg from the Owl."

CHAPTER VIII.

LIFE AND FORCE.

IT used to be the custom formerly to speak of life as "vital force," and to suppose that this force was distinct in kind from the ordinary forces, such as that of heat, or chemical affinity, yet so far similar as to be capable of being transmuted into terms of these forces, so that it could give rise to chemical changes in the same way as these give rise to heat. It is now often denied that there is such a thing as "vital force"; and while some, taking a strictly materialist view, would prefer to suppose that life is only a special case of the action of forces already partly understood by us, such as heat, or chemical affinity, or kindred to these, others prefer to think of it as something of an entirely different nature from any forces that we understand, as something which acts on the known forces somewhat as the known forces act on matter, transmuting them, while not altering them in quantity.

But although we know so little of the nature of life, a good deal has been learnt regarding the general laws of its manifestation; and something must be said, even in the most elementary explanation of the functions of animal life, of their relations with the various

known forces. The chemical changes which are constantly going on in any living creature produce heat, which is very apparent in the case of the higher vertebrates, often spoken of as the warm-blooded, or **homothermous** animals, in which the same temperature is kept up, whatever the outside temperature may be. The blood-heat of man is about 98° F., that of many of the more active mammalia is somewhat more, while birds, from the great activity of their life, are the warmest animals of all. Animals in which the heat produced is less, so that they have a temperature varying with that of the medium they live in, are called cold-blooded, or **poikilothermous**; but many of these show a considerable tendency to be warmer than the surrounding temperature. Efforts have been made to show that the heat produced bears a definite relationship in quantity to the chemical changes which go on in the body; but those efforts must be said to have been unsuccessful, perhaps only from the extreme complication of the problem involved, but probably also from other causes.

Light and electricity are also generated, under certain circumstances, by animal organisms. Light exhibited by animal bodies is called **phosphorescence**, because it resembles in appearance the light presented by certain compounds of phosphorus in the dark. The name does not necessarily imply that the light is evolved by means of the compounds of phosphorus existing in the fats of the organism, although some have supposed this to be the case. The same term is

applied to similar light given off by certain vegetable organisms, especially fungi, and by some flowers.

Some of the Protozoa show phosphorescence, and also many small forms of the Hydrozoa, and these give a vague general phosphorescence to the breaking foam of the sea, which in our climate is usually best seen on a warm summer evening, when the air is somewhat oppressive, as, for instance, in thundery weather, although it may occur on mild days, even towards the winter. One of the best instances among the Protozoa is *Noctiluca* (see p. 138). Among the Coelenterata the larger forms are also often very conspicuous, such as the Girdle of Venus, which is found in the Mediterranean, and the large globular jelly-fish of the Atlantic Seas, which are often several feet across. There are also instances of phosphorescence among nearly every other group of animals, including worms and crustacea. Some molluscs (*Pholas*) are luminous, and several of the ascidians are brilliantly so, especially *Pyrosoma* and *Salpa*. It is to be supposed that the use of phosphorescence to marine animals is to light up their way in the sea, and prevent collision with one another. In this way it would be of great use to the animal bearing the light, so that we can understand why it should exist in the case of some animals which have not eyes themselves, and even of some which have become blind through long residence in the depths of the sea. Numbers of terrestrial insects are luminous, and with them the chief use of the light seems to be as a means of communication, especially

between the male and female. Phosphorescence is probably much more common among insects than we are at all aware of, as the behaviour of all sorts of moths to the candle would suggest. Among the most notable instances are the glow-worm and the fire-flies, which are beetles; and the Chinese lantern-fly (*Fulgora*), related to the Italian grasshopper (*Cicada*). Among the crustacea there are also instances of luminosity. Among the vertebrata, while we find that luminosity is very common in fishes, being exhibited always by some, and at seasons by others, such as the common herring, yet it is doubtful whether it occurs among the higher groups.

In many of the more highly organized animals that exhibit phosphorescence, the light, instead of being diffused all over, is emitted by special organs. The general type of these organs, in whatever part of the body they are developed, seems to be that of a glandular structure, secreting an oily fluid. The phosphorescence is not attended with any heat beyond the natural temperature of any active gland, nor does it seem to consume more oxygen than would be accounted for by other active vital processes; it is therefore not connected with anything of the nature of ordinary combustion. It has been attributed to a slow oxidation of a fatty compound containing phosphorus, phosphorus being, in minimal quantities, a usual constituent of protoplasm, and an important constituent of various animal fatty tissues. Phosphorescence sometimes continues after the death of the

animal, and sometimes occurs in decomposing animals, such as lobsters and some kinds of fish that are not known to be phosphorescent in the live state. There is considerable variety in the colours shown by phosphorescent animals of different kinds. The most common colour is a golden light, with a greenish change; and some creatures change colour when they are disturbed. It is exceedingly probable that the occurrence of phosphorescence is to some extent governed by climatic conditions. Some instances are related of phosphorescence which is of the nature of fluorescence; *i.e.*, the animal only shines when it has previously been shone upon by the sun, or other bright light; possibly this is often the case.

The relations of electric phenomena to the ordinary activities of living bodies are equally obscure with those of phosphorescence. There is a popular idea that the force exercised by nerves, especially the motor nerves, is closely connected with electricity—an idea that is based chiefly on a popular knowledge of experiments of the class that bear the name of their discoverer, Galvani. Aloysius Galvani, a doctor in Bologna (or, according to one version of the story, his assistant), was working with an electric battery, while some dead frogs, intended for culinary purposes, were lying on the table near it; and one of them received an accidental induction shock, which caused it to exhibit muscular movements. I should think that one of the ensuing results must have been, that the Galvani household never ate frogs again;

but the wider consequence was, that the world was made acquainted, about the year 1786, with the fact that an electric shock, communicated to a dead nerve, would startle it into a temporary imitation of its natural activity, in producing movement in the dependent muscles. Swammerdam had in 1678 demonstrated the same fact by another mode of experiment, but this had neither been understood at the time, nor remembered afterwards. This fact is usually shown by means of a "nerve and muscle" preparation, that is to say, a nerve trunk with its dependent set of muscles, dissected out and isolated from the rest of the body of a frog not long dead, in which it may be clearly seen that the communication of an electric shock to the nerve produces a twitching of the muscles, more or less strong according to the force of the current. But it must be remembered, that, since the same result ensues when the nerve trunk is stimulated by giving it a poke, or by touching it with salt or acid or some other irritating chemical substance, the fact that the electric current will do the same does not in the least prove that electricity has anything to do with nerve force.

The occurrence of certain electric currents, of definite direction, in severed muscles, and of similar currents in severed nerves, and the occurrence of other definite currents when a nerve and muscle are put into artificial activity, have led to various theories regarding the connection of electricity with the motor forces of the body; but most of these theories have now been

abandoned. The following explanation of the facts has been offered. The electric currents noticed in a severed muscle or nerve when at rest are due to the electric interaction of dead and living tissue, of which the latter has a higher state of electric potential ; and precisely similar currents are shown by sections of vegetable tissues : it has been proposed to give to these currents the general name of **boundary currents**. Their existence depends upon the injured parts of the severed structure being in a dead or dying state, while the middle and uninjured parts remain alive. The electric changes noticed in a nerve or muscle stimulated to activity are due to a similar interaction between resting and active tissue, in which the resting part would appear to have the higher potential. The stiffness of the active muscle seems to be in a way comparable to the stiffness of death as regards its electric condition ; and it is considered possible that the chemical conditions of the two may also be to a slight extent similar. To these currents that take place in active tissues, it has been proposed to give the name of **functional currents** : they are more complicated in their nature than the boundary currents. It is important to notice that similar currents take place with variations of temperature, the electric potential of warm tissue being greater than that of colder tissue.

It will easily be seen from the above statements, that our present knowledge of the electric conditions which have really been demonstrated to exist in

living bodies is very far from throwing any light on the nature of nerve force, the phenomena observed being those exhibited by protoplasm in general, rather than by nerve or muscle in particular. The effect produced on human beings by changes in the atmospheric electricity is as yet imperfectly understood. Some people are affected in health or temper of mind by an approaching thunderstorm, others not at all. Every one knows that electricity can be generated by rubbing certain substances with a cat's skin, or, in some states of the weather, by rubbing a live cat's fur backward with the hand: electric sparks can similarly be produced by rapidly combing one's hair with a vulcanite comb. But none of these facts can be supposed to have any very important bearing on the investigation of the forces concerned in the functions of animal life.

The existence of electric animals, however, is a very suggestive fact, though their structure is at present quite inexplicable (see p. 263). But all statements regarding any connection of electricity with the animal organism should be received with extreme caution, since this field of inquiry constitutes the "happy hunting-ground" of charlatans. Electrical treatment of various kinds is sometimes used with good results by the physician, but this no more proves that nerve force has anything to do with electricity, than the employment of massage treatment with good results proves that it is identical with mechanical force. Animal "magnetism" is another favourite topic of

the charlatan. Certain so-called sensitives claim that they can feel the presence of a magnet; yet it has been found by experiment that human beings feel nothing when their heads are brought into the field of magnetic attraction excited by the most powerful magnets. It is possible that there are persons exceptionally constituted who are possessed of a special sensitiveness to magnetic conditions; but if so, none of these have yet succeeded in placing their faculty under the criticism of competent observers in circumstances that would preclude all possibility of deceit. The only excuse that I know of for retaining the term "animal magnetism," founded originally on a false theory, is the surmise of a sort of dim analogy between the sympathies of human beings, often most strongly manifested between opposite temperaments, and the attraction which exists between the opposite poles of magnets. It would be premature, though perhaps possible, to suggest that any of the restrictions or modifications of form or function in animal cells present anything resembling polarity.

NOTE.—The student interested in animal electricity should consult Waller's "Introduction to Human Physiology" (Longmans, 1893). A reliable account of "Animal Magnetism" may be found in the article under this heading, by Prof. McKendrick, in the *Encyclopædia Britannica*.

CHAPTER IX.

THE INSTINCT AND INTELLIGENCE OF ANIMALS.

It used to be the fashion to put down all animal intelligence as "instinct," and to consider it as something altogether different from the intelligence of human beings. What "instinct" meant was not always very clearly defined; and the use of the term was often merely a tacit excuse for setting aside the claims of animals to humane treatment and sympathetic study of their idiosyncrasies.

The term instinct, however, is very legitimately applied to a certain class of cases, viz., those in which an animal, placed under special circumstances in which it has never been placed before, knows at once how to act in the manner best calculated to secure its own advantage; and in which every individual of the kind, placed under those circumstances, will act in precisely the same manner. In these cases it is understood that the "instinct" is the result of habit inherited for countless generations. We know very well that this is not usually the case with ourselves; on the contrary, we require in most things the teaching of experience, oftentimes repeated; and no two people, under the same given circumstances, act precisely alike. There are, however, "instincts" that

may reasonably be so termed in the human being as in other animals. The *instinct* of self-preservation, the *instinct* of parental love, dictate actions which few people need to be taught to do. Human races of totally different origin, in widely separated places and times, fashion, to meet the necessities of savage life, the same weapons and the same tools. The ancestral process which is indicated by the term "well-bred" results in *instincts* of delicacy in mind and manners, that render teaching and experience unnecessary. Certain people and certain families, again, have *instinctive* likes and dislikes for certain animals or things. With others, the ability to read human character at sight is an *instinct*, innate and untaught, which the person who exercises it is not able to analyze or explain.

If the term instinct be used in a sense capable of including the results of ancestral experience in human beings too, no objection can be made to its employment.

While some of the cases of action under given circumstances formerly ascribed to instinct may more probably be put down as the result of the acutest reasoning, there are other cases in which apparently wonderful instinct may be largely the work of reflex action. Take the following often-quoted instance from the writings of the Rev. J. G. Wood,¹ who watched the hatching of the eggs of the cuttle-fish,

¹ "Common Objects of the Sea-shore," chap. v.

popularly called sea-grapes. "I was much amused," he says, "with the perfect self-possession of the first that was hatched in my presence. It had not been free from the egg-shell for one minute before it began a leisurely tour of the vessel in which it first saw the light, examining it on both sides, as if to find out what kind of place the world was after all. It then rose and sank many times in succession over different spots, and after balancing itself for a moment over one special patch of sand, blew out a round hole in the sand, into which it lowered itself, and there lay quite at its ease. It executed this movement with as much address as if it had practised the art for twenty years." It would in this case, perhaps, be not very difficult to account for the apparently wise proceedings of the little animal. Just released from the shell, it naturally could hardly help spreading out its feelers; being immersed in water, this resulted in swimming. Tired with swimming, it sank down on the sand, breathing hard; the action of its respiratory siphon, breathing out water all the time, scooped out the sand, and when a hole was made, the animal sank into it. From this point of view, all its actions might be described as the result of the structure of its body, *inevitable* rather than *instinctive*. Still we cannot but contrast its action with the helplessness of the young of the higher animals; for instance, a young kitten kicks about, but does not therefore necessarily walk; but when the young cuttle-fish kicks about, its movements fit in with one another so as to produce swim-

ming. The fact is, however, not that the young cuttle-fish is so especially clever, but that the young cat is especially helpless, as a result of the mother's care exercised throughout untold generations. The apparent absence of instinct in the human being is to be similarly explained: we have lost our physical instincts because we do not need them in the protected condition which our social order affords us. But they have not really disappeared, they have only for the most part shifted their ground, and transferred themselves to the region of mental experience, since with us the struggle for existence is for the most part mental now, rather than physical. Hence human instincts are such as have been already named. The Rev. Gilbert White included musical memory in the list of human instincts, and perhaps with some reason, for talent of each kind, hereditary as it certainly is, seems to be the cumulative product of ancestral experience. In short, instead of drawing a sharp line between the reasoning powers in man and animals, we must recognise that they are the same in kind, though varying in degree and application, according to the structure and mode of life of each kind.

SUMMARY OF THE CHIEF ELEMENTARY FACTS AND PRINCIPLES OF ANIMAL MORPHOLOGY STATED IN PART I.

1. The substance of all animals (as well as of all plants) consists of units, called **cells** or **plastids**, of microscopic size.

2. A cell or plastid consists of a mass of **protoplasm**, containing (in all but a few exceptional cases) a **nucleus**. The latter consists of an aggregated network of firmer and thicker protoplasm, visible as a darker mass.

3. Since division of labour results in economy of labour, cells or plastids acquire various additional characters, to fit them to perform various special parts of the work of the animal body; this is expressed by saying that, in order to perform different **functions**, they become **differentiated in structure**. A mass of cells of similar structure grouped together is called a **Tissue**. When a tissue established to perform a special function is greatly developed, and supplemented by masses of other tissues specially arranged so as to support it and provide it with nourishment, it becomes an **Organ**. Animals in which the body is differentiated into many different kinds of tissues and organs are spoken of as **highly organised**.

4. The most primitive forms of animal life, spoken of as Protozoa, either are **unicellular**, *i.e.* composed of one cell only, or consist of compound aggregates in which separate cells cannot be distinguished. The rest of the animal kingdom, spoken of as Metazoa, have **multicellular** bodies, differentiated into various tissues.

5. The body of the Metazoa consists primarily of two layers of cells, **ectoderm** or outside layer, and **endoderm** or inside layer. The cells of the ectoderm are originally protective in function, and the cells of the endoderm originally digestive, the two layers thus affording the most

primitive case of differentiation into tissues. After the earliest stages of growth, a third layer, the **mesoderm**, is present,¹ lying between the two primary layers.

It is only in comparatively simple forms of the Metazoa, or in the very early stages of growth of the higher forms, that these layers can be seen in their original continuity. In all other cases, they have become greatly folded, contorted, differentiated, and modified, so as to form the various organs of the body. These layers, as they exist in the embryo, are usually called **Epiblast**, **Hypoblast**, and **Mesoblast**, while the names Ectoderm, Endoderm (or entoderm), and Mesoderm, are usually applied in the case of adult animals; the two sets of terms are, however, frequently interchanged (see fig. 23).

6. Every animal in its earliest stage, the egg-cell, is unicellular, like a Protozoan. This cell, after fertilization, divides, and becomes by subsequent repeated divisions first two-layered (**diploblastic**), and then¹ three-layered (**triploblastic**). By the further folding and modification of the layers, the adult form is acquired.

If the animal escapes from the egg before the adult form is acquired, it is called a **larva**; and if the development of the larva proceeds by sudden and remarkable changes, it is said to undergo **metamorphosis**.

7. In the cycle of development which the young animal undergoes, the character of the immediate parent is known to be the last to be assumed, and the earlier stages are understood to represent the characters of various ancestors, less and less remote as development proceeds. (These characters appear in forms modified by the circumstance of enclosure in the egg, or by the conditions of a free larval existence, as the case may be.) The history of the development of the young animal, *i.e.* its **ontogeny**, thus epitomizes, in a modified form, the history of the development of its kind, *i.e.* its **phylogeny**; and by comparison of various types we obtain evidence of the **evolution** of animal life, from simple uni-

¹ In all but the lowest of the Metazoa.

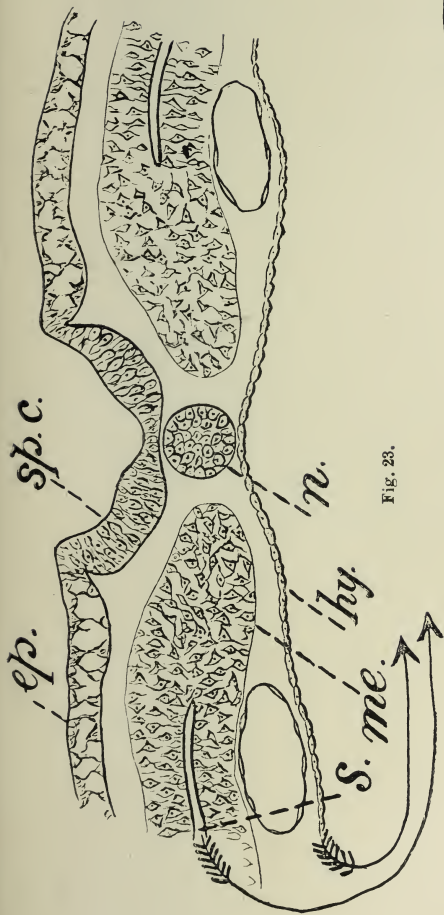


Fig. 23.

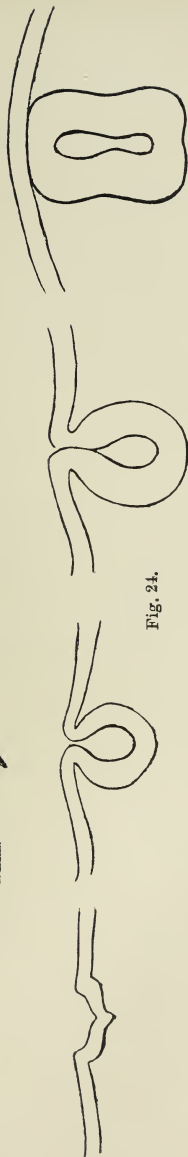


Fig. 24.

Fig. 23.—Transverse section (median portion only) of chick during the second day of incubation, highly magnified : *ep*, epiblast; *hy*, hypoblast; *me*, mesoblast (for structure of cells see p. 42); *sp. c.*, spinal cord, continuous with the epiblast; *n*, notochord; *s*, split in the mesoblast, which is the origin of the body-cavity (p. 41). The arrows show the direction in which the hypoblast and body-wall subsequently develop, so as to meet in the middle line, and thus close the alimentary canal and the body.

Fig. 24.—Diagram showing the stages by which the spinal cord of vertebrates is closed off from the epiblast (see p. 76).

cellular forms, through successive stages, to highly complex organisms.

8. The causes which have determined this process of evolution are believed to be as follows :—Slight **variations** from the parental type of any animal arise from time to time, sometimes fortuitously, but sometimes probably in consequence of the influence of surrounding circumstances of soil, climate, food, etc., which may be spoken of compendiously as the **environment** of the animal. The large number of offspring produced by each animal kind causes a keen **struggle for existence** between them. Any variation that gives its possessor some little advantage over the others will result in the **survival of the fittest**. The survivor will probably transmit its peculiarity, according to the laws of **heredity**, to its offspring, and thus an improved variety will be established. By such small improvements, accumulating through ages of time, the evolution of the animal kingdom is understood to have been accomplished. The same processes are still going on, and we may therefore expect to learn much more about their operation.

PART II.

SYSTEMATIC ZOOLOGY.

CHAPTER I.

THE CLASSIFICATION OF ANIMALS.

THE classification of Cuvier, in the year 1812, which divided the animal kingdom into the four great groups of Vertebrata, Mollusca, Articulata, and Radiata, is the foundation of that now received. Previous to that, the best classification was that of Linnæus { it only provided for two groups of invertebrates, the Insecta, including the animals still called Insecta, and the Worms (Vermes), under which heading were squeezed in all the rest of the animal kingdom, including not only what we call worms, but also the mollusca, or shell-fish, the zoophytes, or radiate animals, and the infusoria, or microscopic animals, so called because they abound in *infusions* of animal or vegetable matter. The classification of Cuvier was a great advance in its recognition of the fundamental importance of the difference between radial symmetry and bilateral metameric symmetry. "The most essential of the modifications which it has become necessary to make in Cuvier's system relate chiefly to the increase of the number of types. The Infusoria were some time ago removed from the Radiata, and as Protozoa arranged by the side of the other four groups. Lately

the number of groups has been increased by the division of the Radiata into Coelenterata and Echinodermata, and of the Mollusca into three groups." The above passage is taken from Claus and Sedgwick's "Text-book of Zoology," in which nine chief divisions of the animal kingdom are given. This is an essentially practical classification, emphasizing the chief great groups, without embodying any special theory regarding their relations with one another, and including under them certain animals that may be regarded as connecting links (*Balanoglossus*, *Amphioxus*). Some prefer a classification that emphasizes the existence of the links by placing them each in an important division all to themselves, and throwing the linked groups, together with the link, all under one larger heading. A classification of this sort is much more easy for the learner, because it makes sure that he will not forget the importance and the meaning of the links.

The nine divisions alluded to are (in ascending order), the PROTOZOA, CŒLENTERATA, ECHINODERMATA, VERMES, ARTHROPODA, MOLLUSCOIDEA, MOLLUSCA, TUNICATA, and VERTEBRATA. By the other mode of classification which has just been referred to, the VERTEBRATES or CRANIATA and the TUNICATA or UROCHORDATA, with the link between them (*Amphioxus*—group CEPHALOCHORDATA), and the link between them and VERMES (*Balanoglossus* — group HEMICHORDATA), are placed under the one great heading of CHORDATA. (See pp. 77, 78, 301.) It will be understood from this, that

the differences of structure which separate these nine groups are not equally great. The relation of the different groups to one another can never be accurately expressed by means of a tabular classification ; it can only be understood by reference to the illustration that has already been used in speaking of the distinction between plants and animals,—namely, that of a branching tree. We may think of the Family Tree of animal life as possessing a main trunk made up of animal types which grow more complex as the trunk rises, and of our nine divisions as having branched off, some quite close to the older stock of very simple types, others very high up, from the newer stock of very complex types. Of the various branches some have, and some have not, sprouted off very near to one another ; and if there stands between two contiguous branches a little twig, belonging to neither, but intermediate in position between the two, this twig may be taken to represent the position of any animal which forms a link between two groups. The diagram on p. 305 will serve to illustrate this analogy, and to indicate roughly the relationship of the chief groups of the animal kingdom.¹

¹ It must of course be understood that this conventional representation of the relations of the various groups of the animal kingdom, although more correct than the representation of them by a tabular series, is still not wholly adequate to express the very complicated ideas involved. It must be added that the details of any such diagram are necessarily to some extent provisional, and that future theories or dis-

The differences between the PROTOZOA and the rest of the animal kingdom are much greater than those existing between any other two of the nine divisions. In some classifications, therefore, this fact is expressed by including all the others under the term METAZOA. The former are distinguished by their comparative simplicity, while the latter have specialized reproductive cells, and a body composed of those definite layers of cells which have been already named (pp. 30, 112). These are the ectoderm and endoderm, with the addition, in all but the lowest forms, of the mesoderm. Some authors prefer to distinguish several **grades** in the Metazoa, the Cœlenterata forming the first grade, the lowest worms the second, and the rest of the Metazoa the third. The first of these grades, *i.e.* the Cœlenterata, has no separate body-cavity, and is, in its lowest forms, practically composed of only the two primary layers. In the next, that of the lowest worms, a separate body-cavity is also lacking, but the intermediate layer is present. The remaining grade comprises that of animals which have a three-layered body, and also a body-cavity of complicated formation.

Different names have been given, by different framers of classifications, to the various large groups,

coveries may necessitate their modification. For instance, a theory has recently been suggested that the ancestors of Vertebrates were much more nearly related to Crustacea than has been hitherto supposed; it will be obvious that the acceptance of any such theory would necessitate a considerable alteration in the Tree.

such as sub-kingdoms, phyla, divisions, classes, orders, etc.; but none of these names can be rigidly applied throughout a classification, because the various groups and sub-groups are not of co-equal value, and to apply the same terms to them is therefore often misleading. But the following system of naming the divisions is that generally followed. Each of the chief divisions of the animal kingdom, sometimes called sub-kingdoms, but now more usually spoken of as **phyla**, is divided into sub-divisions called **classes**, while the classes are again divided into **orders**, and these again into families. The necessities of classification often require also the introduction of intermediate sub-divisions, which may receive various names, such as groups, tribes, sub-orders, etc. Each order usually comprises a number of **genera**, and each genus a number of **species**. It must be remembered, however, in making use of this system of nomenclature, that it survives from a time when the animal kingdom was supposed to have been created in a set of neat little series, so to speak, each made up according to a definite plan, whereas we now know that the differences between different animals are the expression of the outward conditions under which the ancestors of those animals have been placed, and are therefore infinitely various in nature and degree. Therefore, if we agree for the sake of convenience to speak of "orders," or of "classes," we must remember that the distinction between two "classes" in one group may be much greater than the distinction between two

“classes” in another group, and that two “orders” in one class may be very much more alike than two “orders” in another class. In technical language, two classes, or two orders, are not necessarily co-equal in morphological value. It naturally follows that different writers may take different views as to the importance of any given group of animals, and of its differences from other groups; and that group may accordingly appear in one classification as part of an order, while in another classification it forms an order by itself. Similar differences of opinion may exist regarding families or genera, or, in fact, regarding any of the divisions of a classification; hence no two textbooks will be found to give the same classification. Although this fact is very puzzling to the beginner, it has its advantages; for it prevents the learning of a system of classification by parrot-like repetition, and makes the student inquire into and remember the facts on which classification is based.

Each kind of animal receives, in systematic nomenclature, two Latin or Latinized names, of which the first is the name of the **genus**, the second that of the **species**. This method of naming is called the binary nomenclature. It is often a very difficult matter to draw the line between nearly related kinds. The test of identity of species is usually this, that individuals that breed together freely, and produce perfectly fertile offspring, belong to the same species, even if they look rather different from each other. Such differences in colour, size, shape, and habits as may

exist without interfering with perfect fertility, are said to mark a **variety**, or **race**.¹

When several species present certain definite characters in common, they are grouped as a genus; and, in the same way, genera are grouped into larger groups, and these into larger ones again, as may be necessary; while if an animal presents a character quite unique, it may have not only a generic name, but also a class name to itself. In other words, classification is made entirely according to the natural characters of the animals that are classed. Hence, as has been said, no positive system of division into groups is possible in zoological classification; and the only way to understand the classification is to master the natural characters of each group by itself.

The student should make a habit of assigning its place in classification to every animal as soon as he becomes acquainted with it: it is all very well to know the species and variety, but these should be the *last* things ascertained, after its general position has been made clear. Let the beginner in zoology call to mind all the most familiar animals:—horse, dog, cat, rabbit, rat; sparrow, fowl, hawk, seagull;

¹ The student must note that extremes meet in the use of the word "race," which sometimes is used to denote a subdivision of a species, and sometimes is used (as a translation of the word phylum) to denote one of the largest subdivisions of the animal kingdom. The student must also be warned that genera and species are but too frequently recorded under different names by different writers, especially in the earlier literature of zoology.

lizard, frog, and newt; herring, minnow, eel, sole, and cod; oyster, cockle, snail; butterfly, cockroach, bee, and ant; earth-worm, leech, and so on. Make sure which of the great groups of the animal kingdom they belong to, as may be done with the help of this little manual. Ascertain the order, genus and species by reference to some larger work, and then write down all in neat order. For an example of the way in which the beginner should write down information regarding the place of any animal in classification, see pp. 302, 304.

NOTE.—The necessity of mastering the different classifications of the animal kingdom given by different authors is one of the chief difficulties that trouble the beginner in Zoology. The student should therefore endeavour to form, and to keep constantly in mind, a clear idea of the way in which classifications are made, and of the purpose for which they are made. Place in classification is, as will easily be understood, simply a concise way of stating the degree of resemblance, near or remote, which the various members of the animal kingdom bear to one another: thus, animals that are almost exactly alike belong to the same species, and animals that are somewhat alike may belong to the same genus, family, order, class, or phylum, the resemblance becoming more and more remote in the upward order of these divisions. The place of any given kind of animal in classification depends, therefore, on the individual judgment of the writer as to its degree of resemblance with other forms. Hence there may be considerable differences between classifications made at the same period, and by writers who are in possession of the same facts; and the reader may find that in one part of the animal kingdom the classification of one author best commends itself to his judgment, and in another part of it that of another.

Moreover, the discovery of new kinds of animal, or of new facts about old ones, brings into notice features of resemblance or difference among the various groups of animals which have not hitherto been regarded, and thus constantly calls for the alteration of existing systems of classification. Hence, in studying classification, only the newest text-books are of use.

The student should carefully consider the reasons which determine the placing of different kinds of animal in one class. Let us suppose that most of the kinds of animal placed in a given group have half a dozen different characteristics in common: then very likely it will be found that there are a few other kinds which do not possess these six characteristics, but possess five of them; a few others which possess four, or three, or two, or one. If these are included, then the definition of the group must be accordingly narrowed, so that perhaps some of the most striking features of the major portion of the group have to be excluded. The best way to define such a group is, therefore, to take some one animal which has a number of characters in common with a large number of the members of the group, and, considering this as a type, to establish our group not by a definition, but by comparing its members with the type. Thus, the earthworm may be taken as a type of the higher worms (annelids), and the lobster as a type of the Crustacea. In the words of Whewell, "Natural groups are best described, not by any Definition which marks their boundaries, but by a *Type* which marks their centre. The Type of any natural group is an example which possesses in a marked degree all the leading characters of the class." A natural group is therefore "determined, not by a boundary without, but by a central point within—not by what it strictly excludes, but by what it eminently includes." "A Natural System" of classification is thus one "which attempts to make *all* the divisions *natural*, the widest as well as the narrowest," and "applies *no* characters *peremptorily*."¹

¹ The student may with advantage read the chapter on Methods of Natural Classification in Whewell's "*Novum Organon Renovatum*" (Lon-

So much for the manner of classification; a word must be said about its meaning. All classifications have been endeavours to present the members of the animal kingdom in groups according to their more or less likeness with one another, and to arrange these groups in a gradual series linking the highest and the lowest forms.¹ The older writers, however, in arranging their series, preferred to present it in inverse order, *i.e.* beginning with the highest types; and they did not place among inquiries falling within the scope of human knowledge, those questions which would so naturally suggest themselves to us,—as to *how* and *why* these likenesses and differences exist among animals, and *why* the groups of the animal kingdom should be capable of being arranged in a graduated series. Makers of classification in the present day understand, on the contrary, that classification implies an answer to these questions. Likeness of structure is understood to imply community of descent. The graduated series of animal forms is understood to present the traces, preserved among surviving forms, of the evolution of animal life through a series of types, of which many have been lost, while others still survive. From this point of view, one single character may be of more importance in determining the position of an animal in classification than all its other organs.

It will be understood, from the above considerations, that a good deal must be learnt about zoology before the simplest

don: Parker & Sons, 1858), from which the above quotations are taken. Such portions of Whewell's "History of the Inductive Sciences" as refer to the same subject may also be consulted, bearing in mind, however, that the scientific classifications referred to are those of a past date.

¹ Although the groups of the animal kingdom may thus be so arranged in a linear series, it must be borne in mind that such a series, so far as it is linear, is artificial. Just as, in the tree of our diagram, the highest twig belonging to a lower bough may rise above the lowest twig belonging to a higher bough, so the highest members of a low group may reach a point of complexity of organization superior to that obtained by the lower members of a higher group. Therefore a linear series, such as we have in the successive pages of a text-book of zoology, will not represent the complexity of these relationships, which can only be illustrated by a map or diagram.

system of classification can be comprehended in the least. While it was customary in old-fashioned teaching of Zoology to begin by teaching the system of classification, this is now, on the contrary, for the reasons above indicated, the last thing to be learnt; and the student's first lessons in the laboratory are, on the contrary, the careful examination and description of the details of structure in a few kinds of animal. (For mention of text-books arranged according to this plan, see Part III., Chap. I., p. 312.)

Although a real understanding of their meaning is not possible until a considerable amount of detailed knowledge of several different types has been acquired, yet some preliminary acquaintance with the names of the chief divisions of the animal kingdom is useful even to the beginner, and therefore a short summary of the facts of classification is given in the subsequent chapters.

CLASSIFICATION BY TYPE.

The following brief descriptions of *Amœba*, *Vorticella*, *Hydra*, and *Lumbricus*, are given as examples of classification by type.

I. Types of the Protozoa: first grade of animal life, unicellular organisms.

Protozoa: animals more or less resembling the Proteus Animalcule *Amœba* (various species exist; *proteus*, *quarta*, *verrucosa*, etc.): see figs. 26 and 27, p. 135.

Amœba is a nucleated unicellular organism which reproduces itself simply by division into two equal parts (fission); a process of conjugation between two individuals has, however, been observed, and interpreted as a sexual process. The protoplasm of the cell consists of an inner granular layer, the endosarc, surrounded by a clear outer layer, the ectosarc; and contains an excretory structure, the contractile vacuole (or contractile vesicle), a contractile space filled with fluid

The cell constantly changes its shape, throwing out irregular prolongations of its substance, called pseudopodia. Food particles may be absorbed through any portion of the semi-fluid ectosarc; a "vacuole of ingestion" appears round them as they pass in, and a similar "vacuole of excretion" when the undigested residue passes out. In most of these characters it is closely resembled by many forms of animal cell, which are therefore spoken of as amœboid or amœbiform.

Position as a type of its sub-kingdom. Many species of its own class, which differ considerably in the adult form, have young stages which are almost indistinguishable from *Amœba* except in size; the young stages (myxopods) of some organisms in the class Infusoria also resemble it in many respects.

Habits. *Amœba* is a microscopic fresh-water organism found crawling on weeds in stagnant and muddy water. It eats both animal and vegetable organisms, digesting the proteids only, and rejecting the starch and fat.

Development. The young *Amœbæ* produced by fission are exactly like the old ones in everything but size.

Place in classification. Sub-kingdom **Protozoa**; class RHIZOPODA; order *Foraminifera*; sub-order *Lobosa* or *Amœbiformes*; genus *Amœba*.

Detailed description. See Huxley and Martin's "Practical Biology"; Parker's "Elementary Biology"; and Howes' "Atlas of Practical Elementary Biology."

The class INFUSORIA are Protozoans more or less resembling the Bell Animalcule, *Vorticella* (various species, *microstomum*, etc.). See fig. 122, p. 303.

Vorticella is a stalked bell-shaped unicellular organism with a contractile vacuole and large horseshoe-shaped nucleus (endoplast). It is more highly specialized than *Amœba*, affording an instance of the highest degree of differentiation of parts which is obtained by single cells. It cannot, like *Amœba*, throw out pseudopodia, or ingest food at any point; it pos-

sesses, on the contrary, a fixed outline, a definite channel for the entrance of food—the “gullet,” and a fringe of cilia. The latter are small—equal-sized permanent processes of protoplasm, which by their vibration create a current in the water, and drive food into the “gullet.” Vacuoles of ingestion and of excretion are seen as in *Amœba*. Reproduction may take place by fission into two equal halves, of which one remains fixed, while the other is a free-swimming form, provided at the base with an extra ring of cilia instead of a stalk. It may also take place by what is spoken of as “spore formation” or as “gemination (*i.e.* budding) from the endoplast,” the nucleus breaking up into a number of parts, from which originate small free-swimming forms. A small form is also sometimes produced by unequal or by repeated fission of one of the ordinary stalked forms. Conjugation is observed to take place between one of the small forms and an individual of the ordinary stalked form, the former being absorbed into the latter.

Position as a type of its sub-kingdom. *Vorticella*, as has been already stated, affords an instance of the highest degree of differentiation attained by single cells. It is accordingly one of the higher types of its sub-kingdom.

Habits. *Vorticella* is a minute animal just distinguishable by the naked eye. It is a fresh-water form, found in ponds, fixed on weeds, sticks, and animal organisms.

Development. The small free forms produced from “spores” become fixed in time, losing the lower ring of cilia by means of which they swim, and developing a stalk instead; they then grow till they attain the usual size.

Place in classification. Sub-kingdom **Protozoa**; class INFUSORIA; order *Ciliata*; sub-order *Peritricha*; family *Vorticellidæ*; genus *Vorticella* (*see* p. 302).

Detailed description. See Huxley and Martin’s “Practical Biology”; Parker’s “Elementary Biology”; and Howes’ “Atlas of Practical Elementary Biology.”

II. Type of the Cœlenterata: second grade of animal life, diploblastic animals with no distinction between body-cavity and alimentary canal.

Cœlenterata: animals more or less resembling the Fresh-water Polyp, *Hydra* (various species, *viridis*, *fusca*, etc.). See fig. 11, p. 46, fig. 30, p. 149.

Hydra is a small cylindrical animal with a mouth, and arms called tentacles. It agrees with all other types of Metazoa, in being a multicellular organism, and in having special cells, the ova and spermatozoa, differentiated for the purpose of sexual reproduction; but it differs from them in the following particulars: viz., it is diploblastic (p. 29); it presents no distinction between body-cavity and food-canal (p. 40), the digestive cavity being a simple sac¹ with no opening besides the mouth (p. 168); the ectoderm, especially of the tentacles, is armed with stinging structures called nematocysts² (p. 148), and there is a perfect radial symmetry,³ shown in the presence round the mouth of a ring of tentacles, usually six or eight in number, each of which is lined by endoderm, and contains a hollow space prolonged from the enteric cavity.

Although *Hydra* is described as diploblastic, the third body-layer of higher animals is to some extent represented by a thin "supporting lamella" or mesogloea (p. 143); this lies next to a layer composed of contractile processes sent out by the ectoderm cells, which constitute a rudimentary form of muscle. Certain cells in the ectoderm are interpreted as nerve-cells; while others (cnidoblasts) give rise to the nematocysts already named. Thus, although the body of *Hydra* has not attained to the possession of "organs" (unless we may dignify with that name the groups of cells which form the ovaries and spermaries), yet the cells of the ectoderm have attained a considerable degree of differentiation. The cells of the endoderm, which are remarkable for presenting

^{1 2 3} Hence the names Cœlenterata, Cnidaria, Radiata.

very large vacuoles, retain an amœboid character. When food has been swallowed, they reach out pseudopodia, or finer processes called flagella, to catch solid particles. The latter are ingested by the substance of the cells, just as occurs in *Amœba*. This process is spoken of as "intracellular digestion."

Position of the type in its group. The organism which has been chosen as a type is in this case one of the simplest forms presented by its group; the higher forms present a greater complexity of structure, and may possess nerves and sense-organs. From many of its group it differs in not being a permanently fixed form; it does not, however, move with much freedom. In addition to the power of sexual reproduction, it retains the power of asexual reproduction by budding, a process which is very characteristic of the Cœlenterata. The buds of *Hydra* are thrown off; in other cases, where they remain attached, colonial forms are produced, such as corals and corallines. By the alternation of forms which are only capable of budding with special forms, which are capable of sexual reproduction, "alternation of generations" may be produced (p. 150). But in *Hydra*, owing to the fact that the buds are set free, no colony is formed, and no "alternation of generations" takes place. In this respect, *Hydra* is therefore not typical even of the order to which it belongs (*Hydromedusæ*).

Habits. The *Hydra* is a minute fresh-water form, found standing on water-weeds, in ponds and ditches. It catches small organisms with its tentacles, benumbs them with the sting of its nematocysts, and swallows them.

Development. In *Hydra*, as in other Metazoa, the fertilized egg-cell, produced by the union of a spermatozoon with an ovum, divides by two, and then again and again by two, until a mass of cells is formed. Varying accounts have been given of the development of *Hydra* in its further stages; but the development of allied forms presents a ciliated larva of elon-

gated form, consisting merely of ectoderm and endoderm surrounding a median cavity. This larva, called a planula, subsequently acquires a mouth and tentacles.

Place in classification. Sub-kingdom **Cœlenterata**; class **HYDROZOA**; order *Hydromedusæ*; sub-order *Eleutheroblastæ*; family *Hydroideæ*; genus *Hydra*.

Detailed description. See Huxley and Martin's "Practical Biology"; Parker's "Elementary Biology"; Howes' "Atlas of Practical Elementary Biology."

III. Type of the higher Vermes, which, together with the remaining sub-kingdoms of the animal kingdom, constitute the fourth grade of animal life, triploblastic animals with a body-cavity surrounding the alimentary canal.

(The study of the third grade, represented by forms belonging to the lower **Vermes**, is omitted here.)

Vermes. Animals more or less resembling the Earthworm, *Lumbricus* (various species, *terrestris*, etc.).

The Earthworm is a bilateral (p. 81) animal, with a body divided into segments or metameres (p. 83); it differs from *Hydra*, and agrees with all the higher types of animal life, in possessing a third body-layer, the mesoblast (p. 30), and a body-cavity (pp. 40, 46) surrounding the alimentary canal. It has no limbs, and exhibits a characteristic crawling movement, typical of its sub-kingdom, and effected by the contraction of successive regions of the well-developed muscular coat of the body-wall, which consists of an internal longitudinal layer, and an external circular one. (In the earthworm external bristles aid in crawling by taking a firm hold on the ground, but many worms are smooth.) The body has attained a much higher stage of differentiation than that presented by *Hydra*. The following organs are present:—*Nervous System*, consisting of a paired dorsal ganglion or "brain," united, by connectives which pass round the pharynx, with a double ventral longitudinal nerve-cord; organs of special senses are

not developed: *Alimentary Canal*, surrounded by a body-cavity; distinguished into successive regions called pharynx, gullet, crop, gizzard, and stomach-intestine, and possessing a separate and posterior excretory aperture (anus): *Vascular System*, containing colourless corpuscles in a red fluid, and consisting of several main longitudinal trunks, of which the chief, supra-intestinal and supra-neural, are connected in the anterior region by six pairs of vessels: *Excretory System*, consisting of paired tubes called nephridia or segmental organs, lying in successive segments: *Reproductive System*, consisting of male and female organs, both present in every individual.

The metamerism of the body is indicated in the following particulars: ringed muscular walls of the body, marking off successive segments; successive ganglia of the longitudinal ventral nerve-cord; presence of the segmental organs in successive segments; partitions across the body-cavity, called mesenteries, which keep the alimentary canal firm in its place, and correspond with the boundaries of segments.

Development. The development, as just stated, is direct, no larval form being developed. The student must refer to *Polygordius* (p.179) for a type of the development of the Vermes, which throws light on the formation of the mesoblast and body-cavity.

Habits. The Earthworm is a burrowing terrestrial animal, several inches long, which lives on leaves, vegetable mould, and the small organisms contained in it. It is nocturnal, coming to the surface of the ground at night.

Place in classification. Sub-kingdom **Vermes**; class ANNELIDA, sub-class CHÆTOPODA; order *Oligochæta*; sub-order *Terricolæ*; family *Lumbricidæ*; genus *Lumbricus*.

Detailed description. See Huxley and Martin's "Elementary Biology"; Howes' "Atlas of Practical Elementary Biology"; Marshall and Hurst's "Practical Zoology," and Thomson's "Outlines of Zoology." For description of *Polygordius* and its larva, see Parker's "Elementary Biology."

CHAPTER II.

THE PROTOZOA.

Animals more or less resembling in structure the *Amœba* (*see* p. 127).

Classes.—RHIZOPODA, or *Amœba*-like animals.
INFUSORIA, or *Vorticella*-like animals.

THE PROTOZOA are minute animals which are either unicellular or else composed of indefinite protoplasm, not presenting any division into cells. In the latter case the organism may be either polynuclear or non-nucleated. They reproduce themselves without forming definite egg-cells and sperm-cells like those of other animals. The Protozoa are all water animals with the exception of some parasitic forms, and of one or two kinds of *Amœba*, which have been described as living in damp sand.

The chief divisions, or classes, of the Protozoa, are the RHIZOPODA, or root-footed animals, so called because their most characteristic feature is, that they have root-like processes or filaments of protoplasm (*pseudopodia*), which help them to move and catch their food; and the INFUSORIA, originally so called because they appear in abundance in *infusions* of vegetable or animal matter.

The Rhizopoda include the orders *Foraminifera*, *Heliozoa*, and *Radiolaria*. The former have received their name from the fact that some of them have little

shells, in which there are fine holes or *foramina* traversed by threads of protoplasm. The dead shells of Foraminifera of this type compose the ooze of the Atlantic bed; and the ooze of past geological periods, known to us in the form of chalk, is also

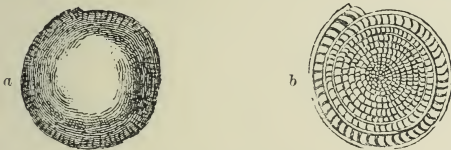


Fig. 25.—A Nummulite: a, exterior; b, seen in section.

composed of the same material. The largest of the fossil Foraminifera is called the *Nummulite* (fig. 25), or money stone, from its round shape. It is found so abundantly in the limestone of the Eocene period, that the limestone has thence received its name, and

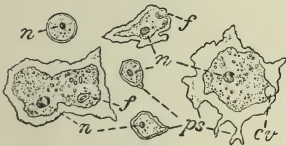


Fig. 26.



Fig. 27.

Fig. 26.—Magnified specimens of *Amoeba* (small ones): cv, contractile vacuole; n, nucleus; ps, pseudopodia; f, small organisms taken in as food. The three smaller specimens are shown in a more or less retracted state, the two larger ones more active. All show an inner granular layer, the endoplasm, and an outer clear layer, the ectoplasm. (The boundary line between these appears in the cut somewhat too distinctly marked.)

Fig. 27.—Changes of outline presented by a single *Amoeba*: 1 to 16, during a period of four minutes; 17 to 26, during a further period of three minutes.

is called the Nummulite limestone. The Rhizopoda also include the soft shell-less *Amoeba*-like forms, of

which the *Amœba* ("Proteus animalcule") has been already described as the typical form of the animal cell. It is a single cell, furnished with a nucleus and a contractile vacuole: its protoplasm, divided into an inner granular layer called the endoplasm, and an outer clear layer called the ectoplasm, is constantly in movement, throwing out or retracting pseudopodia, and thus altering its shape.

The *Heliozoa* (sun-animals) are so called because they have stiff radiating pseudopodia all round, which make them look like a conventional representation of the sun with its rays. They are, as a rule, provided with a silicious (flinty) skeleton. They are freshwater forms, and have a contractile vacuole, which distinguishes them from the next order. The *Radiolaria* are marine forms, which have a skeleton often very like that of the *Heliozoa* in appearance. Their skeletons, like those of the Foraminifera, have formed geological deposits: being of a silicious character, they sometimes form a hard stone, useful for polishing slate. An interesting fact about the *Radiolaria* is that they are often found to contain coloured unicellular plants (algæ), which have been described under the name of "yellow cells." These are believed to be, not parasites, but companions, each member of the partnership deriving some advantage from it. Companionship of this kind is called *symbiosis* (living together).

The higher types of the INFUSORIA are more highly organized than the Rhizopoda. Instead of having a

more or less jelly-like exterior prolonged into temporary or stationary branches (pseudopodia), they have a firm, almost membranous exterior, and they move by means of **cilia**. Cilia are short processes of protoplasm, which are usually placed in rows. They have an active vibratory movement, by which a current is created in the surrounding water. A long unbranched process, called a flagellum, is also borne by some Infusoria. The *Infusoria* have always a contractile vacuole, and many forms have a mouth. They are divided into two orders, the *Flagellata*, or Monads, and the *Ciliata*. The former are so called because their distinctive feature is the possession of a flagellum: some forms have two. These abound in infusions of decaying organic matter, and some kinds especially in infusions of decaying fish. The stage which has a long flagellum is called a mastigopod (whip-footed animal). Some forms of this sort have been seen to issue in numbers from an encysted parent form. In some cases these young mastigopods develop afterwards into an amœboid stage. Sometimes several of them fuse to form an amœboid body. The non-nucleated Flagellata are placed by Haeckel in a group called Monera (Monads).

The amœbiform stage is sometimes referred to as a myxopod (jelly-footed animal, *i.e.* one with pseudopodia). The position of this group, and of individual members of it, is not very certain; for some of the animals assigned to it may not be adult forms, and some of the compound amœboid forms may be only a

temporary case of conjugation. The typical *Flagellata* seems to have something like a mouth; at least, the entrance of food is confined to one special region. The largest kind belonging to this group is the brightly phosphorescent *Noctiluca* (night-glow), which is found in the English seas. It has a thick appendage or tentacle, a mouth, which is guarded by a tooth-like prominence, and a vibratile flagellum.

The *Gregarinidæ* form a group of the Protozoa which is usually placed near the above. They are parasitic animals; are long in shape, and sometimes have an anterior portion differentiated off from the main cell, which serves to fix the organism to its host, and gives it a false appearance of being bicellular. After conjugation, the Gregarine encysts, and forms oval spores provided with a hard case, which are called *pseudonavicellæ*, from their shape, which resembles that of the diatom *Navicula* (one of the *Algæ*, or simplest forms of plant). When these are ripe, the cyst bursts and lets them out: then each breaks its envelope as a myxopod, *i.e.* amœbiform cell.

The *Ciliata* have not only a mouth, but also an anal region, for the expulsion of undigested particles. They have a nucleus with a conspicuous nucleolus, which was described, before its true nature was understood, under the name of Paranucleus; this latter undergoes conspicuous changes during the process of multiplication, and is to be considered comparable in a measure with the nucleolus of other growing cells (p. 20).

Something has already been said as to the reproduction of *Vorticella*, one of the best-known types of the Infusoria. It is a bell-shaped animal on a stalk, with a mouth which is protected by a ciliated flap, the moving cilia of which keep up a current that whirls food particles into the mouth: hence its name of *Vorticella* (little whirlpool). Other forms, which are free-swimming, have belts of cilia distributed all over them. *Vorticella* may be noted as possessing striped protoplasm, by means of which it appears to execute its contractile movements, and similar stripes are seen on the tentacle of *Noctiluca*. These are believed to be the most primitive form of striated muscle, the difference being, that in the latter the stripes extend across the protoplasm of a series of contiguous and confluent cells, instead of across a small portion of the protoplasm of one cell. There are many other stalked forms besides *Vorticella* (figs. 122, 123, p. 303). The majority of the order are, however, free-swimming.

The Protozoa do not always reproduce themselves in the way which has been described in the case of *Vorticella*. The organism may divide without the occurrence of any previous fusion of two cells; that is, it may reproduce itself asexually. It is believed, however, that this process cannot go on indefinitely, and that, after repeated multiplication by division the conjugation of two cells (fig. 21B, p. 80) eventually becomes necessary as a condition of the occurrence of further division. Division into two may take place, or division into a number of very small cells, which in

this case are called "spores." As for the fusion of two cells, it is said to take place sometimes without the occurrence of subsequent division, the object being merely to produce a stronger cell: this afterwards parts into two, which may sometimes be equivalent to the original couple: this process is called rejuvenescence.

With regard to the proper classification of the Protozoa, considerable difference of opinion has existed. Some would prefer to place first, as the most simple and elementary forms, those kinds which have no nucleus (*Monera* of Haeckel, included under the heading of *Flagellata*); but it is probable that these will eventually be found to be only a stage of some form which, in another stage, does possess a nucleus; and even if they should be found to be permanently non-nucleated kinds, yet it would still remain to be inquired whether they might not be degenerate types which had lost a nucleus which their ancestors possessed (just as the red blood corpuscles of the mammalia are degenerate cells which have lost the nucleus possessed by the less highly specialized red blood corpuscles of the other vertebrates), and whether they should not therefore be respectively placed, in classification, near to those forms which they most resemble in general appearance.¹

¹ In some classifications, also, there are included with the Protozoa some organisms which are usually supposed to be vegetable, *e.g.*, the *Volvocineæ*, often classed with the vege-

Ditch water and stale infusions of vegetable or animal matter will supply the student with a rich variety of the Protozoa. The empty skeletons of the marine and the fossil forms are frequently seen as microscopic objects; but these are of little use to the student.

table kingdom as Algæ, and the Bacteria, or *Schizomycetes*, usually considered as a low type of Fungi. For the position respectively of these as classed in the vegetable kingdom, see Prantl and Vines's "Text-book of Botany."

CHAPTER III.

CŒLEENTERATA.

Animals more or less resembling in structure the Freshwater Polyp (*see* p. 130).

Classes.—PORIFERA, or Sponges.

ACTINOZOA, or Sea-anemones and Corals.

HYDROZOA, or Jelly-fish and their allies.

CTENOPHORA, or *Cydidippe* and its allies.

CNIDARIA.

THE CŒLEENTERATA are multicellular radiate animals with no distinction between body-cavity and digestive cavity (*see* pp. 40, 46). The body contains a simple cavity, the **enteron**.

Some of the lower forms of the Cœlenterata (*Hydra*) possess practically only the two primary body layers, ectoderm and endoderm, the mesoderm being present only in a very rudimentary form: such an animal is said to be **diploblastic**, *i.e.* possessed of (only) two body-layers, while the majority of animals are described as triploblastic, *i.e.* consisting of three layers. This is regarded as the most primitive and ancient type of the Metazoa; for it is comparable with the two-layered gastrula, which has been described as a stage of the embryonic development of many animals: hence we may suppose that the rest of the Metazoa are descended from an ancestor of this kind, and for this hypothetical ancestor the name of **gastræa** has been proposed. So great indeed is the difference

between the Cœlenterata and most of the other Metazoa, that it has been proposed to divide them from these, and place them in a separate and lower grade. There are, however, indications of the third layer even in Hydra, and in others of the Cœlenterata it is much more conspicuous; but it differs greatly in character from the third layer of higher animals, and is therefore usually referred to under the special name of **mesogloea**.¹ In Hydra it is spoken of as the middle lamina, or as the supporting lamella.²

The Cœlenterata include the PORIFERA or Sponges, a group which differs from other animals in having a branched digestive cavity (enteron), and the CNIDARIA, or nettle-animals, so called from their power of stinging their prey.

The PORIFERA have been one of the puzzles of Zoology, and it is only quite lately that it has been possible to compare the structure of the sponge with that of other animals. A sponge consists of a jelly-like substance strengthened by a skeleton of hard matter, which, in the dead and dry state, forms what is known commercially as sponge. In the live state, there is a circulation of water through the canals which permeate the substance of the sponge.

The circulation in the canals is maintained by the cilia of the cells which line them. This lining layer

¹ A name given on account of its texture (Gk. γλοιά, glue or anything sticky).

² Diminutive of Lat. *lamina*, a very thin plate.

is the endoderm (see p. 73). The main substance of the sponge, which contains and secretes the skeleton, is composed of Amœba-like cells, forming a firm and contractile flesh, or parenchyma¹; this corresponds with the mesoderm, or middle layer of the animal body. The outside layer, or skin, called the ectoderm, consists of a thin flat layer of epithelium cells (see p. 41). The parenchyma layer contains specialized male and female cells (spermatozoa and ova): the latter are amœboid and motile.

The surface of a sponge is perforated by holes, whence the group receives its name of Porifera. These holes are of two kinds, small and large, called respectively pores and oscula. Canals, lined with cells derived from the ectoderm, pass from the pores into the substance of the sponge, and open into small chambers. Each of these gives rise to another tube, and by the union of this set of tubes a large canal is formed, which opens into an osculum. The water, carrying with it food particles, enters by the pores, and is exhaled through the oscula. The chambers and exhalent tubes are lined with endoderm.

The sponge, like the vast majority of invertebrate animals, has a larval stage. The larva, which is at first a free ciliated form, fixes itself, and becomes a simple tube with one osculum: the sponge, as we usu-

¹ Literally, stuff employed in filling up (Gk. ἐγ-χέω, to fill up by pouring in); a name employed to designate the substance of various tissues composed of similar cells or parts.

ally see it, is a compound animal, in which the number of oscula represents the fused units. This compound animal may be composed of successive buds branching off from the original stock, or of several stocks, originally distinct, which have touched and fused ;

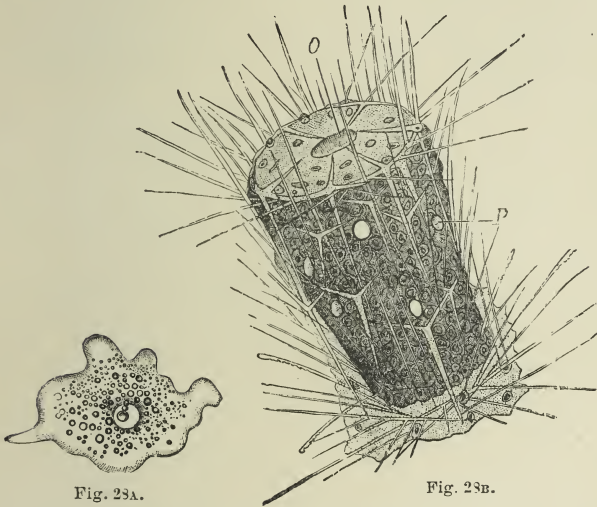


Fig. 23A.

Fig. 23B.

Fig. 23A. — Amœbiform cell from the parenchyma of *Spongilla* ; highly magnified.

Fig. 23B. — A young Sponge, *Sycon* : o, osculum ; p, pore. (From Claus and Sedgwick, after Fr. E. Schulze.)

and usually the growth of a sponge consists of a mixture of both processes.

The formation of the larva of the sponge is not observed to be the same in different kinds of sponge, but differs widely ; and while, on the whole, it seems probable that the structure of the body is to be inter-

preted in the way already named, viz., as representing the three usual body-layers, yet the different forms of larval development that have been observed are difficult to reconcile with each other, and much remains to be learnt about the sponges. They were formerly supposed to have no structure beyond what has been stated; but cells have been described in some kinds of sponge, which have been interpreted as rudimentary sense-cells.

The Sponges have been classified according to the nature of their skeletons: one group includes sponges with calcareous skeleton, the others, respectively, sponges with no skeleton, with horny skeletons, silicious skeletons, and skeletons mixed of both. These skeletons usually consist chiefly of isolated spicules (needles), which present very curious and beautiful shapes, and are favourite objects for the microscope (fig. 29).

Sponges may be abundantly found on rocks and bits of seaweed near low tidemark on our coasts, though the large species that we buy in the dry state are the growth of warmer seas. They are brilliantly coloured, orange and olive-green being among the commonest kinds. There is also a green fresh-water sponge, *Spongilla*, which is found in English streams.

The CNIDARIA are divided into two classes, the corals, ANTHOZOA (flower-animals) or ACTINOZOA (ray-animals), and the jelly-fishes, HYDROZOA, or POLYPOMEDUSÆ. Besides these, another division, the CTENOPHORA, is sometimes made into a separate class.

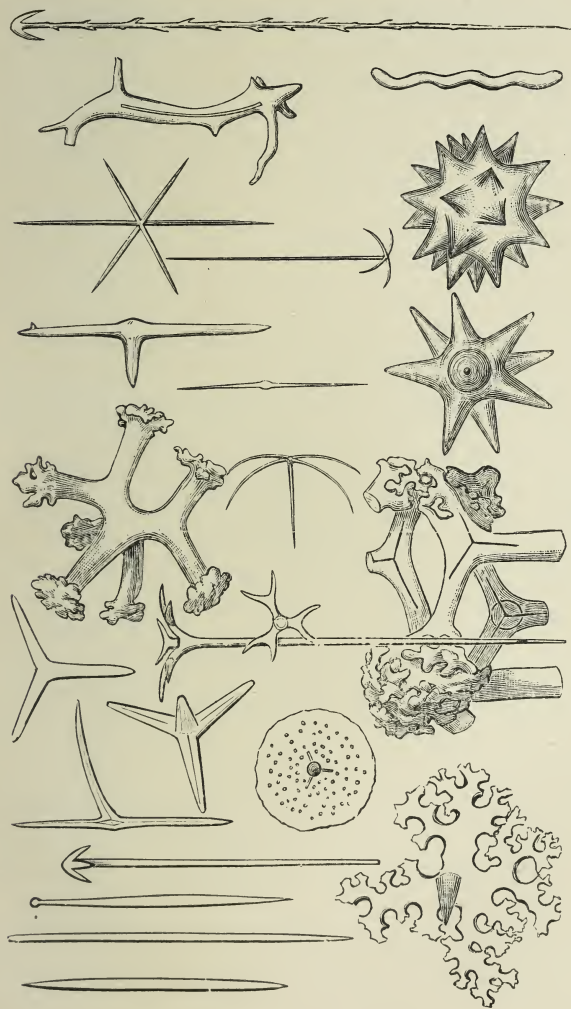


Fig. 29.—Spicules of different kinds of sponge.

The Cnidaria are characterized by peculiar stinging cells, or **nematocysts** (thread-bags), developed from certain cells called **Cnidoblasts** (nettle-formers). Each of these contains a long thread coiled up, which is sent out to its full length to inflict the sting. The use of these is to paralyse the prey on which these animals subsist. The stinging powers of certain jelly-fish, well known to bathers, have procured them the name of *Acalepha*, or Sea-nettles. Like that of the vegetable nettle, the poison of the sea-nettles affects some skins very much more than others.

Many of the forms belonging to this group are fixed; hence their radial symmetry (see p. 82), which is expressed, so far as their outward form is concerned, by the arrangement of their **tentacles**, which surround the mouth. These tentacles are arms, capable of being extended at length, or retracted into a small space, and provided with numbers of the stinging cells already described. When they touch anything, they retract, carrying the object with them as a rule, and conveying it to the mouth, if it is suitable for food. In the Actinozoa and in *Hydra* these tentacles are round, and contain a cavity that communicates with the internal gastric cavity.

Many Coelenterata have a two-layered ciliated larval stage called a *Planula*,¹ which after a time usually fixes itself to some object, and thus gives rise to a fixed form.

¹ So called because by means of its cilia it is able to move about (Gk. *πλανάομαι*, to wander about).

While we call this a larva, it must be remembered that it is equivalent to a stage which is still enclosed in the egg, in higher and more slowly growing animals. The beginner must guard against the mistake of supposing that all larvæ are equivalent: the larva of a higher form, on the contrary, usually represents the

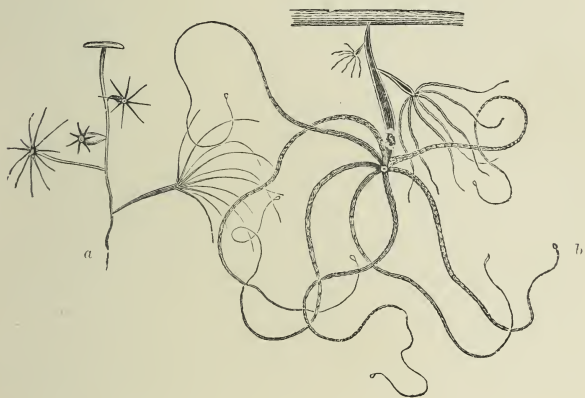


Fig. 30.—Specimens of the Brown or Long-armed Hydra, *Hydra fusca*, adhering to a bit of wood: *a*, several individuals, natural size; *b*, an individual with two asexually produced buds, enlarged.

adult stage of a lower form, from some variety of which, according to the principles explained on p. 55, it is then supposed to be descended.

One of the simplest forms of the Cœlenterate animal is found in *Hydra*, the fresh-water polyp (p. 131).

Colonial or Compound Animals. The most remarkable feature of this group is the tendency to de-

velop colonies, or compound animals, formed by the development of single ones successively budded off from, but remaining connected with, the starting-point of the first organism. Each of the units is called a "polyp," or "zooid," or "person;" while the whole colony is called a zoophyte; the substance which connects the successive units with one another is called the *cænosarc*, or *cænenchyma*, i.e., common flesh, or common substance. Corals are the most familiar instance of this kind of development, which occurs in all the chief divisions of the Coelenterata. Somewhat similar colonies occur in some Ascidians (*Tunicata*), and in the Bryozoa, or Moss-corals (*Polyzoa*) (pp. 231, 237). It will easily be seen that a colony of this kind presents an alternation between sexual and asexual reproduction, the first individual being the product of a true egg, or specialized female cell fertilized by a specialized male cell, while the rest of the colony are derived from this first individual by a process of division. The individuals thus produced bear sexual organs, just the same as those produced in the ordinary way; and thus we have an alternation of reproductive processes.

Alternation of Generations. The above describes the state of things that exists in the colonial Anthozoa, but when this alternation of reproductive processes is accompanied by a specialization in form of the polyps destined to bear the reproductive organs, the animal is described as presenting "alternation of generations," or *metagenesis*. This is what happens frequently in the Hydrozoa (see p. 158). When this is

the case, the reproductive polyps assume the specialized type characteristic of the group, *i.e.*, that of a Medusa, or jelly-fish, while the ordinary polyps are more like *Hydra*, the simplest form of animal in the group. They are therefore spoken of respectively as medusoid polyps and hydroid polyps.

The animals that exhibit "alternation of generations" afford some of the most complicated problems of morphology; and there are cases in which it is rather difficult to distinguish between an alternation of this sort and the alternation of forms which is apparent in an animal which has a larval stage that looks very different from the adult stage.¹

¹ It is interesting to compare the state of things we find in many of the Coelenterata with the alternation of generations that happens in plants, the details of which may be summarized here, since they may not be known to the reader. Those green plants which have vascular stems and leaf-ribs, but do not bear those coloured expansions of modified leaves surrounding the essential organs, which are popularly known as "flowers," are called *Vascular Cryptogams*; * they include the mosses and ferns and other allied plants. The ferns,—for instance the Common Bracken Fern,—show the typical form of alternation of generations in plants. The "fern," as known to us, is the asexual generation of the plant, which is produced from a properly fertilized egg, or *oosphere* (egg-sphere), as the vegetable egg is called. On the back of the leaf (or frond, as a spore-bearing leaf is called) are developed, in masses called *sori*, protected by a covering called the *indusium*, the *spores*,

* *Vascular*, *i.e.* containing *vessels*. The "vessels" of plants are pipes of thickened or woody tissue of various forms, which serve the double purpose of conveying fluid and of supporting the soft cellular tissue. Tissue of this sort does not exist in the lower cryptogams—cryptogams, *i.e.*, plants with a hidden (inconspicuous) flower.

The *Actinozoa* owe their flower-like appearance to their tentacles, which, as already stated, are arranged

spore being the name given to vegetable structures with hard coats, which are like seeds, only produced asexually, that is to say, without undergoing any process of fertilization. The spore, falling on any damp surface, splits and germinates, exactly like a seed, and from its growth there is developed

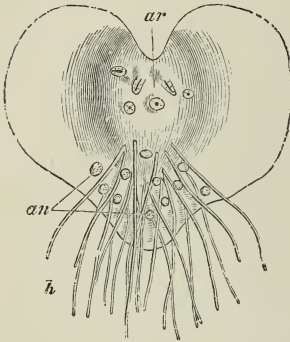


Fig. 31.—Alternate generation of a fern; prothallium, or sexual plant. Under side ($\times 10$): *ar*, archegonia; *an*, antheridia; *h*, root-hairs. (From Prantl and Vines' "Text-book of Botany").

the sexual generation of the fern—a small, flat, green leaf, called the *prothallium* (or frond-let), which has small hairs for roots, and has on its lower surface hollow cases of two kinds, called *antheridia* and *archegonia*, which respectively contain the male cells, *antherozoids* (animal-like male bodies, so called because they have the power of moving about, which they accomplish by means of their active cilia) and *oospheres*, or egg-cells. From the oospheres, fertilized by the antherozoids, there are developed in turn specimens of the fern. The large fern and

the small green leaf, or prothallium, are spoken of respectively as the sporophore (spore-bearing) or asexual generation, and the oophore (egg-bearing), or sexual generation of the fern. In certain more highly specialized forms of the vascular cryptogams, it is found that these prothallia are very much reduced in size and importance, so that sometimes they only just project from the spore; while they are also distinguished into two sorts, those which bear only antherozoids and those which bear only oospheres. The

in radial symmetry round the mouth. The mouth opens into the œsophagus or gullet, a short tube lined

spores which bear the former kind are those called *microspores*, those which bear the latter kind *macrospores*. This is a step towards the state of things that exists in the so-called flowering plants, more correctly spoken of as *Phanerogamia*, or showy-flowering plants. In these the prothallium is much reduced: the male prothallium is represented by the root-like pollen-tube, which germinates from a pollen grain which has fallen on the stigma of a flower, but no antherozoids are ever produced by it, and the pollen-tube itself passes directly into the seed to fertilize it. The female prothallium is so reduced that it never passes outside the spore-coat, which is represented by a structure called the embryo sac, lying inside the ovule (as the unripe seed is called), and usually gives rise only to a single oosphere. It now exists as the endosperm of seeds, or albumen, as it is called, from its usual chemical composition. One of the links by which its real nature is traced is found in the *Coniferæ*, or Pine-tree family, where there are seen in an early stage of the ovule several oospheres in the endosperm of one seed, each surrounded by a group of cells which represent an archegonium. The endosperm persists as the outer substance surrounding the embryo in the kernel of the pine-cone. The substance of this seed, therefore, is the homologue, or representative, of the little green leaf-like prothallium of the fern, which, from being an independent plant, has become reduced to a mere organ of the asexual plant, or sporophore. The endosperm is utilized as a source of nutriment for the embryo in the ripened seed: but in some seeds it becomes obliterated, so that there remains nothing of it but the embryo developed from the essential oosphere, and in this case the cotyledons, or first pair of leaves, are enlarged by the deposit of food-stores so as to fulfil the same purpose; while in other seeds it is supplemented by an exterior layer of albumen called perisperm. The flower

with ectoderm, which hangs down freely into the general cavity of the body. Vertical partitions, called **mesenteries**, project from the body wall into the enteron; some of these pass up into the space round the œsophagus, and thus divide that space into a number of chambers, which communicate above with the hollow tentacles. These mesenteries occur in pairs. In the young animal their development shows traces of a bilateral arrangement, and may indicate that the radial structure of the actinia is secondary, and derived from a primitive bilateral type.

Sense cells are found in the outside layer of the body of the *Actinozoa*, and superficial nerve cells connected with them; while muscle fibres sometimes appear in the middle layer. The animals are usually unisexual, and the sexual cells are situated on the mesenteries.

of the sporophore bears on its stamens and pistil respectively the pollen-grains and the ovules, which are the homologues of the cryptogamic spores; these produce sexual cells, so that it appears to be a sexual plant. It will be seen from the above facts that alternation of generations, though exceptional among animal forms, is the general type of development among plants. The main difference in the development of alternate generations as exhibited by plants is, that it is complicated by the additional feature of the existence of the asexual spore, a link between the two forms with which there is nothing quite comparable in the animal series.

For details regarding the above facts, see "Text-book of Botany," Prantl and Vines; Parker, "Lessons in Elementary Biology," Lessons xxix. and xxx.; also *Encycl. Brit.*, art. "Reproduction—Vegetable," by S. H. Vines.

The majority of the Actinozoa secrete a hard supporting structure known as "coral." Its importance as the material of "coral reefs" is well known; nor has it been less in past ages of the world, for corals are often abundant in geological formations, and even extensive reefs are not unknown. The gastric cavities of the polyps often remain connected with one another, so that the coral is channelled all through, the new polyps not being closed off in budding.

The two chief divisions of the Actinozoa are the

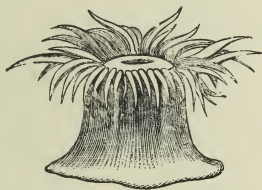


Fig. 32.—The Snowy Anemone, *Sagartia nivea* (from Claus and Sedgwick, after Gosse), showing tentacles and mouth.

Alcyonaria and *Zoantharia* (Madrepores), formerly called *Octocoralla* and *Hexacoralla*. The commonest English representative of the former is the *Alcyonium*, popularly called Dead-man's Fingers; the Sea-pen (*Pennatula*) is sometimes found on our coasts; it is so called from its shape, which is something like that of a quill feather, owing to the polyps being arranged on the stock in a definite bilateral manner. The *Gorgonia*, or sea-fan, the red coral of the Mediterranean, and the organ coral, or *Tubipora*, are among the chief foreign representatives of the order.

In the English sea the *Zoantharia* are chiefly represented by the common sea-anemones (*Actiniæ*), which are single polyps with no skeleton. Their flower-like appearance has given them their name, many of the species being beautifully coloured. One of the finest, known as the Dahlia anemone, is banded with bright crimson and attains a very large size, often considerably exceeding that of the flower it is supposed to resemble. The common coral of the Eng-

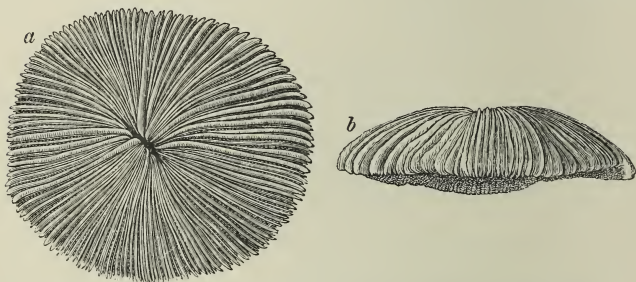


Fig. 33.—Mushroom coral, *Fungia*: a, view from above; b, side view.

lish seas is the Cup-coral (*Caryophyllia*), which is a polyp much like the sea-anemone, but secretes a hard coral. The majority of the showy corals brought from abroad, such as the Brain-stone corals and Mushroom corals, belong also to this order.

In the Madrepores (*Zoantharia*), the “coral” or calcareous skeleton is secreted by the outer layer of the body (ectoderm), folds of which project inwards into the chambers between the mesenteries, pushing the two other layers in front of them; in these folds

are found calcareous radiating plates known as **septa**. Thus the coral lies, morphologically speaking, outside the body of the polyp, although the septa project into the enteron. The edges of the septa are seen as characteristic ridges on the inner rim of the calcareous cup, or **theca**, which is left when the polyp has

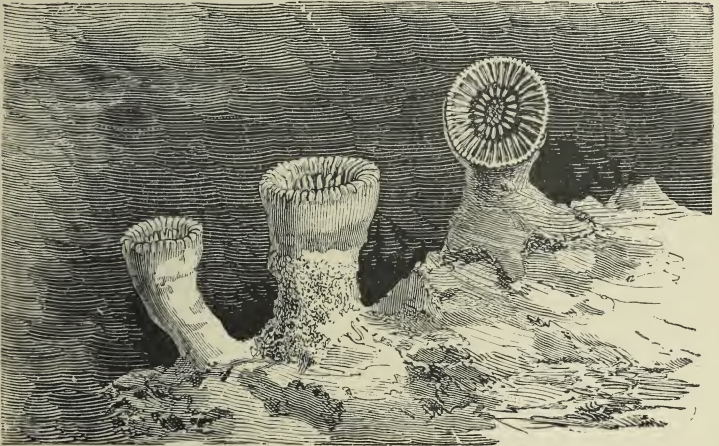


Fig. 34.—An English coral, *Caryophyllia cyathus*.

decayed. These are the so-called Sclerobasic corals ; the reef-building corals are of this kind.

In the *Alcyonaria*, on the contrary, the skeleton is found in the mesogloea, though it is considered possible that the cells which secrete it may have migrated there from the ectoderm. In *Alcyonium* it consists of free calcareous spicules (needles) ; in *Tubipora* these unite to form the tubes ; in other *Alcyonaria* loose spicules

are present in addition to a supporting skeleton. The latter may be horny (sea-fan, *Gorgonia*), composed of horny and calcareous joints alternately (*Isis*), or all calcareous (red coral, *Corallium rubrum*). These are the so-called Sclerodermic corals.

In the HYDROZOA, as already stated, there is frequently an "alternation of generations." The polyps produced by division adopt that principle of the "division of labour" (which has been spoken of on p. 24 as the secret of the differentiation of cells and tissues), so that some of them only fulfil digestive functions, while others develop reproductive functions and produce eggs; while in some cases others again degenerate, lose even the digestive organs, and are useful merely to protect the others. These are spoken of as "nutritive zooids"¹ or "persons," and "reproductive zooids"² or "persons," and "protective zooids" or "persons." The reproductive persons, under these circumstances, frequently become free, and float about as independent animals. In this stage they form what are commonly known as **Medusæ**, or "jelly-fishes"; and they are exactly like certain other forms of jelly-fish, which are complete and single animals: animals, that is to say, which do not form a colony, but produce from one egg one zooid only, which is complete in structure, possessing the reproductive in addition to the other organs and functions of animal life. In some forms all the polyps are much modified with a view to their respec-

¹ Trophosomes.² Gonosomes.

tive functions. In many the reproductive polyps are so much reduced that they appear to be only organs, and not individuals of a colony; they were named **blastostyles** (reproductive buds) or **gonophores** (carriers of the reproductive organs) before their morphological value as separate individuals was fully

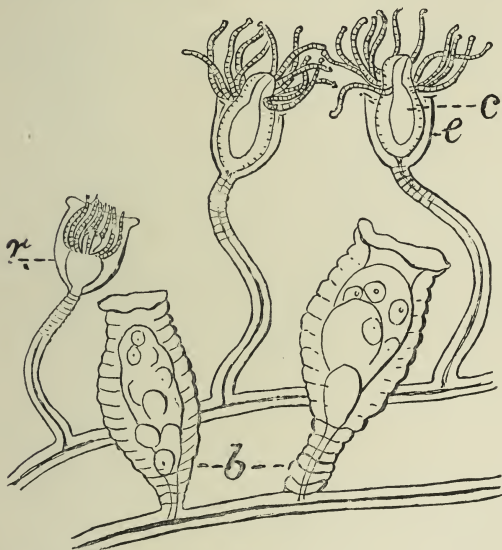


Fig. 36.—Blastostyles, *b*, of a colony of hydroid polyps; *r*, hydroid polyps retracted, *e*, expanded; *c*, enteron or digestive cavity, seen in optical section. (Magnified.)

recognised. The fully-formed medusa is to be regarded as a highly differentiated form of polyp, which is often flattened out and largely modified with a view to the necessities of a free-swimming existence. It will be noticed that the medusa, compared with the

polyp, is upside down: the polyp is fixed, mouth upward; the medusa floats, mouth downward, its "umbrella," or dome, corresponding with the fixed end of the polyp. The medusæ have the mouth situated in a central hanging disc, called the **manubrium** (handle). The gastric cavity, owing to the shape of the animal, is not elongated, as in the polyp, but spreading. It has branches, which are called the **radial canals** or **gastro-canals**. Many medusæ possess a nervous system in the form of a ring, and sense-organs, some of these being rudimentary eyes (ocelli), and some rudimentary ears (otocysts). There are three orders of the Hydrozoa: the *Hydromedusæ*, the *Siphonophora*, and the *Acalepha*. The *Hydromedusæ* are colonies of fixed polyps; the sexual polyps are either free medusæ or fixed medusiform buds which never get to the free stage. One of the simplest animals in this order is *Hydra*. This, however, though in many respects typical, differs in being a single polyp, and not fixed. Like others of the polyps of the *Hydromedusæ*, it has the middle layer of the body very slightly developed, so that the body wall at first sight seems to consist of only two layers, the ectoderm and endoderm. The ova of *Hydra* are amœboid cells, somewhat like those of the sponges. It reproduces itself frequently by asexual buds, which do not remain attached for long, but soon become independent. Many of the colonial *Hydromedusæ* secrete horny tubes, the part that surrounds the polyp being called the *hydrotheca*. The stem has a central cavity continuous with the gastric cavities of the polyps (fig. 35).



Fig. 36.—The Straw Coralline, *Tubularia indivisa*.

Many forms are common on our coasts, under the popular name of corallines. *Tubularia* (Fig. 36) has long straight tubes containing single polyps. *Antennularia* has straight tubes with short verticillate branches: *Sertularia* branches in one plane, *i.e.*, is bilateral like a leaf or feather; *Plumularia*, the sickle coralline, has feather-like branchlets arranged on a spiral axis. *Campanularia* has bell-shaped heads borne on an irregularly branching stalk. This order presents the fixed generative buds called blastostyles. The medusæ, when free, are usually rather small. They have a nerve ring round the disc, and sense-organs connected with it. These sense-organs are not especially protected, and the order has therefore received the name of *Gymnophthalmata*, or naked-eyed medusæ, in distinction from the *Steganophthalmata* (covered-eyed medusæ), *i.e.*, *Acraspeda* or *Scyphomedusæ*, described below. The most easily distinguished feature about the medusæ, however, is the existence of a fold, turned in along the margin. This is called the **velum** or **craspedon** (*i.e.*, veil or border), and from its presence this order has also received the name of the **Craspeda**. The order contains not only forms with a hydroid stock, but also some forms (*Trachymedusæ*) which are developed directly from the larva, and never have any hydroid stage.

The *Siphonophora* have carried the principle of the division of labour to such an extent, that their polyps are hardly to be recognised as such, while the medusoids rarely become free. The whole colony forms a

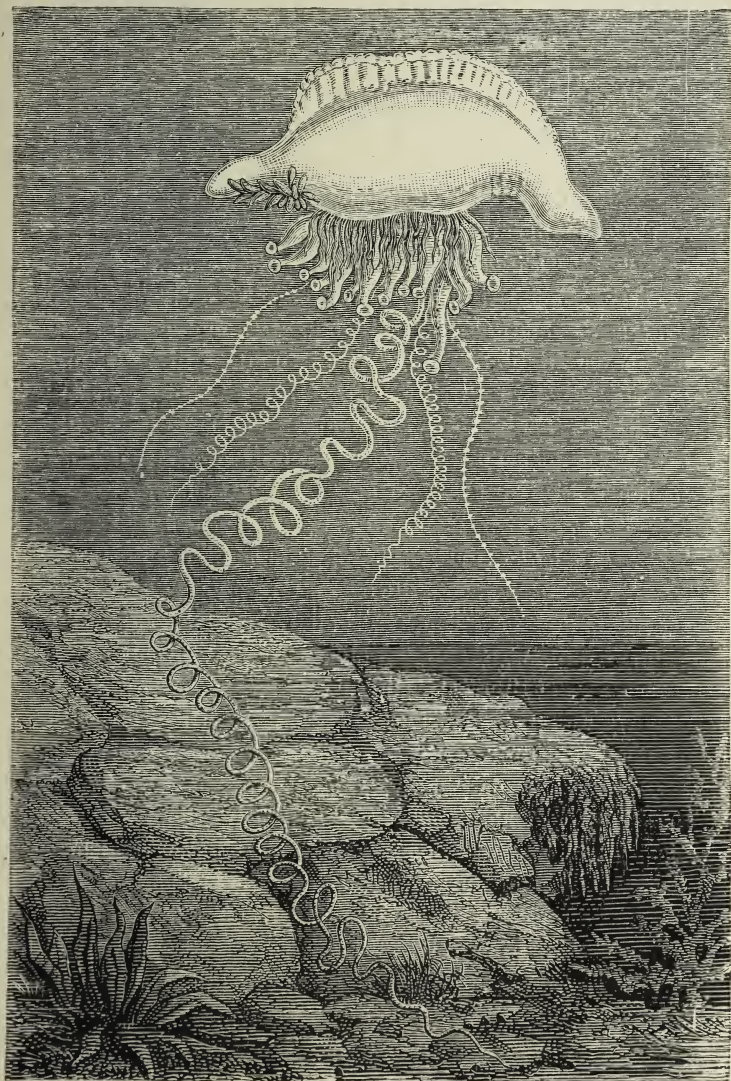


Fig. 37.—The Portuguese Man-of-War, *Physalis utriculus*.

floating body, and is called the *hydrosoma*. It has a float at the top, which contains a contractile air-chamber, the use of which is to keep it upright, and to raise it to the surface of the water, or depress it as required: these are called the *pneumatophore* and *pneumatocyst*. The nutritive zooids have tentacles full of thread-cells: and besides the reproductive zooids, there are sometimes protective and degenerated zooids of several kinds. The *Physulia*, or Portuguese Man-of-War, comes sometimes to our shore from warmer seas. It receives its name from its appearance, as it sails on the surface of the sea with its pneumatophore rising above the water. It stings virulently if touched (Fig. 37).

The *Acalepha*, or *Scyphomedusæ*, have no colonial stage, but are usually developed from a larval form, though they sometimes develop directly from the ciliated embryo. The larval form is very peculiar; it first exists as a larva with tentacles called a *Scyphistoma*. From this a succession of buds with tentacles are developed one within another, row after row, like a fir-cone, and from its appearance the larva is called a *Strobila* (fir-cone): these buds, after further development, split transversely away from one another and become separate medusæ. The *Lucernaria* is a small fixed form of the same order, which may be found occasionally attached to seaweeds, etc.: it is very like a small eight-armed medusa inverted and fixed by the top of the umbrella. It is therefore in the same position as the polyps of the *Hydromedusæ*, but does not in the

least resemble them, being medusiform in its shape (Fig. 38). It is believed to develop direct from the

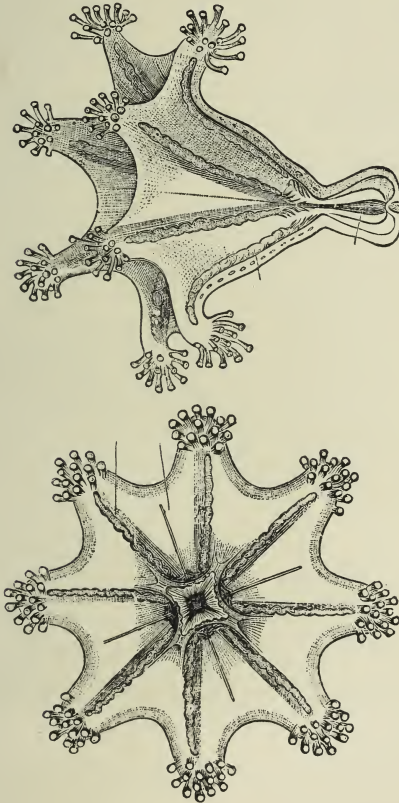


Fig. 38.—*Lucernaria* (enlarged) (From Claus and Sedgwick.)

ciliated embryo. The *Scyphomedusæ* are also known as the *Acraspeda*, because the medusa forms are

without a *velum*. Jelly-fish of this order may be distinguished from other types by the features of the margin, which is divided into lobes, in the interstices of which the marginal sense-organs lie protected:

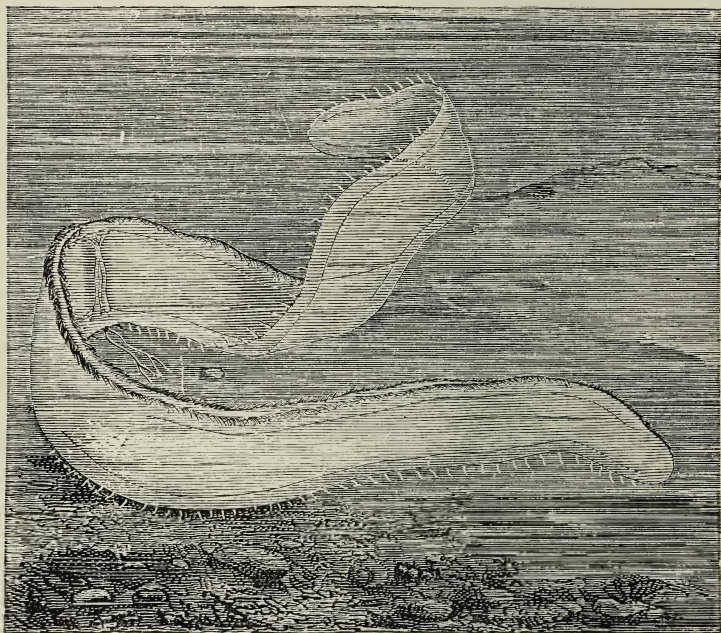


Fig. 39.—The Girdle of Venus, *Cestum veneris*.

hence the order has also received the name of the *Steganophthalmata* (medusæ with covered eyes).

The *Ctenophora* are sometimes made into an order of the Hydrozoa, and sometimes made into a separate

class of the Cœlenterata. They are medusoid (jelly-fish-like) animals, and receive their name (comb-bearers) from possessing parallel bands of cilia. They have a special modification of the thread-cell, which is sticky at the end, and fixes instead of stinging its prey. They have sense-organs similar to those of the medusæ. Some are nearly round, but though they have a symmetry in some respects radial, they have traces of acquired bilateral structure due to an active swimming life; and some are bilaterally flattened. They propel themselves by means of active cilia. The gastric cavity, which is called the *infundibulum*, is affected by this bilateral symmetry, so that it assumes a compressed form. The *Cydlippe* is a common kind in English seas: it is about the size of a marble, and is a very pretty form, with two long ciliated tentacles. The highly phosphorescent "Venus' Girdle" also belongs to this group (Fig. 39).

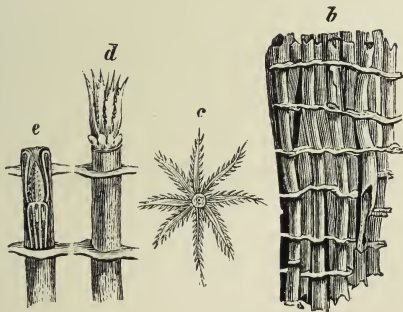


Fig. 40.—The Organ Coral, *Tubipora musica*, one of the Alcyonaria (p. 155).

CHAPTER IV.

ECHINODERMATA.

Animals more or less resembling in structure the Sea-urchin.

Classes.—CRINOIDEA, or Stone-lilies.
ASTEROIDEA, or Star-fishes.
ECHINOIDEA, or Sea-urchins.
HOLOTHUROIDEA, or Sea-cucumbers.

THESE are the first animals in which we meet with a body-cavity (see p. 40) surrounding the alimentary canal, and an excretory opening, or anus.¹ Lying in this body-cavity there are (i.) the alimentary canal, (ii.) the reproductive organs, male and female, and besides these, structures which have no existence in the Coelenterata, the **Vascular System** or system of blood-vessels, and also a unique set of structures called the **Water-vascular System**. This consists in the starfishes of a hollow ring, with little bags or vesicles (bladders), called the **Polian vesicles**, attached to it, and it communicates with a large number of other and much smaller little bags on the outside

¹ Some of the higher infusoria (*Paramœcium*) have a separate region for excretion; one of the sea-anemones (*Peachia*) has been said to reserve one side of the oral aperture for this use; and the *Ctenophora* are exceptional in possessing two definite excretory apertures.

of the animal (presently to be described), called the **ambulacral tubes**, or feet. The whole system is filled with fluid, and by means of this the feet can be inflated at will, so that the animal can push them out to walk with or draw them back when it is at rest. The fluid in this system is indirectly in communication with the sea-water outside, by means of a tube which is called the stone-canal, and which ends exteriorly in a structure called, from the curved pattern on it (which is like the winding outlines of the madreporé, or brain coral), the **madreporiform tubercle**. The water-vascular system arises in the larva, as a branch of the body-cavity.

The Echinodermata used to be considered to be radial animals like the Cœlenterata, and were included by Cuvier in his Radiata, along with these. But their radial symmetry appears to be secondary, as well as incomplete, for they are derived from a bilateral larva, as well as being irregular in the adult stage. Roughly speaking, however, they have in the adult a pentamerous symmetry (*i.e.* composed usually of five parts). The true position of the group with regard to others is very uncertain; all that can be said positively is, that its larval stages resemble those of such worms as have a larval stage, so that we may suppose the two groups of animals to be in some way connected.

The *Echinodermata* are only placed before the Worms in classification for the sake of convenience, because nobody knows what place to give them; for among the varied groups that are put under the heading of

Worms, there are forms that must be looked on as much lower.

The *Echinodermata* are divided into the following classes: the CRINOIDEA, or Stone-lilies, the ASTEROIDEA, or Starfishes, the ECHINOIDEA, or Sea-urchins, and the HOLOTHUROIDEA, or Sea-cucumbers.

The first are fixed forms, with a jointed stalk, bearing the animal (forming the *calyx*, or cup) at the end, like a flower. The mouth is at the middle of the calyx, and there is an anus situated near it. The water-vascular system branches, not into "feet," as in the Starfishes, but into the divisions of the tentacles, called pinnules, from their likeness to the small divisions of a fern frond: they are very small, and very numerous. Both the stalk and the cup, together with the branched arms that surround the cup, are hardened by calcareous deposits. Hence the animal is well preserved in the fossil state, to which most of the species belong, this being one of the groups which have passed their maximum development, and are now on the decline. The fossil forms abound in the limestones of the Carboniferous and other Palæozoic rocks; the cup is only found in particularly good specimens, but the stalk joints are exceedingly common, forming pretty objects, in which the central canal, that in the living form contains bloodvessels, presents various symmetrical shapes when seen in section. The living representatives of the class are mostly deep-sea forms; but one, the Feather-star (*Comatula* or *Antedon*), is found on the English coast. It is of a pink colour. The larva is

free-swimming, has a mouth and anus, and four parallel bands of cilia arranged transversely to the length of

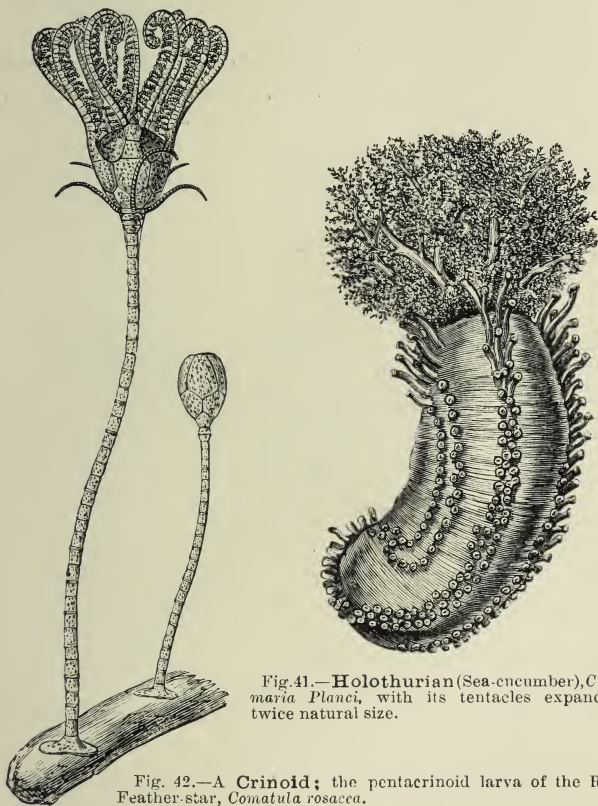


Fig. 41.—**Holothurian** (Sea-cucumber), *Cucumaria Planci*, with its tentacles expanded; twice natural size.

Fig. 42.—A **Crinoid**; the pentacrinoid larva of the Rosy Feather-star, *Comatula rosacea*.

the body. The rudiments of the adult form are developed within it while it is still free: afterwards it

becomes fixed, and the outer part is lost, setting free the crinoid; this, however, is only fixed for a time, the adult form being able to move about in a slow way, by movement of its arms.

The Starfishes, or ASTEROIDEA, have a star-shaped body, usually with five rays, but sometimes more.

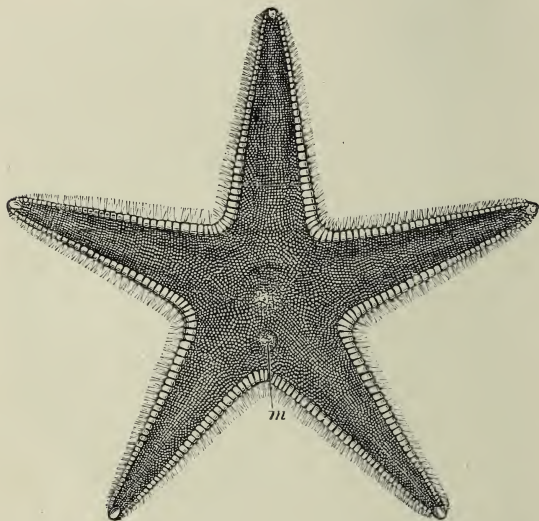


Fig. 43.—A Starfish, *Astropecten irregularis* (reduced): *m*, madreporiform tubercle, which marks the centre of the **bivium**, viz. the two rays on each side of it. The three remaining rays form the **trivium**.

From the traces of bilateral symmetry shown by the animal, these are sometimes spoken of as divided into two sets, the **bivium** and **trivium**. The “feet” are on the lower (oral) surface only, and they have a skeleton of hard pieces protecting them; and on

the aboral surface, where those are absent, the skin is strengthened by calcareous plates, armed with small blunt spines and knobs of various sorts. The mouth is in the middle of the lower surface upon which the animal crawls, hence called the oral surface, while the excretory aperture is on the upper surface.

The common Starfish (*Asterias*) is exceedingly destructive to oysters and other shell-fish. The Sun-star, *Solaster*, has numerous rays, and is of a beautiful deep crimson, varying to pink. The Brittle-stars (*Ophiuridæ*), which form a separate sub-class, have long, thin, snake-like arms; hence their name. They afford some instances of a tendency to get rid of the larval stage; for while most of the Starfishes have a free larva, some of them (*Amphiura*) are viviparous, and the young do not undergo metamorphosis.

The Starfishes walk by means of their "tube-feet," which are arranged in rows on the under side of the rays; each has a sucking disc at the end of it. The rows of tube-feet have received the name of *ambulacra*, or walks: hence the hard structures which guard them are called "ambulacral ossicles," and the groove down each ray, on each side of which they are symmetrically arranged, is called the "ambulacral groove"; while the water-vascular system is also spoken of as the "ambulacral system." The way these feet are used is as follows: first, a number of them are pushed out to their full extent, then they catch on with their suckers, contract, and so bring the animal on a little; and the same process is repeated.

Examine the nerves of the common Starfish, which may be seen by pushing aside the tube-feet near the middle line of the rays. They form the central line seen on the under surface of each ray. They are not cords of tissue like the internal nerves of other animals, found on dissection; but they are *outside* and *flat*. They are covered only with a very thin layer of epithelium, and may be regarded as mere thickenings of the skin. *In other words, we have here the primitive*

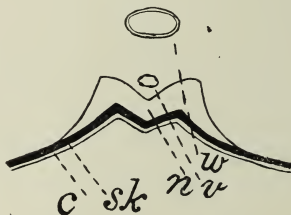


Fig. 44.—Position of nerve in arm of starfish, as seen in transverse section : *c*, cuticle; *sk*, skin; *n*, nerve lying next the skin; *v*, section of vessel; *w*, section of vessel belonging to the water-vascular system.

form of nervous tissue derived from the outside body-layer (ectoderm = epiblast), and not yet tucked in and separated from its parent tissue, as in other forms. The same is the case with those of the Jelly-fish; but those of the Starfish are here especially mentioned because the animal is so common as to be familiar to every one.

The ECHINOIDEA, or Sea-urchins, receive their name from the fact that they are covered with spines. These spines are movable, and in the common Sea-urchin, which has rather large ones, they may easily

be seen to be fitted on by a sort of ball and socket joint, of which the ball is left behind as a tubercle, if the spine is pulled off. In some Sea-urchins (*Cidaris*) there are only a few spines, and those very large compared with the size of the urchin. The urchin is enclosed in a calcareous box, composed of numberless small plates. In the common urchin, five interlapping double rows of these correspond with the five ambulacral grooves of the starfish, with their opposite ossicles: while between are five other interlapping double rows inter-radial in position; these pass from the apex to the mouth, which is exactly in the centre of the lower surface. The former contain tube-feet, which pass through very minute pores in the shell (easily seen when the shell is dry), and spines also; while the latter are covered with spines only. Sea-urchins have also other external appendages, called **pedicellariæ**, modified spines, which are like a bird's beak on a stalk, and keep snapping constantly, and the function of which is probably to remove waste particles. The common Sea-urchin has a very complicated apparatus of teeth; these are in the form of a five-partite cone, the five sharp ends peeping out as sharp teeth, while on dissecting the apparatus each is found to be attached to a long comb-like saw. In *Cidaris*, *Echinus*, and their allies, the shell is so nearly round as to be described as **regular**, while the ambulacral areas are said to be **perfect**, *i.e.*, they run uninterruptedly from the apex to the mouth. In the other forms the ambulacral

areas are modified and interrupted, and have a special rosette round the apex, which marks the situation of an area of modified ambulacral tubes; and from the flower-like shape of this rosette these urchins are said to be **Petaloid**. This is the case in the Heart Urchins, order *Spatangidæ*, of which the common Heart-urchin (*Amphidotus cordatus*) of the English coast is an example, and in the Flat Urchins, order *Clypeastridæ*. One of the most familiar of the latter is the Sand-cake of the North American coast, which is as flat as a thin biscuit. These various forms are correlated with the habits of the animal; the very round urchins, like *Echinus*, can walk about among stones, like starfishes; the Heart-urchins live partly buried in sand or mud, and are a transition towards the flat ones, which are suited for lying flat on sand. Many animals that live on sandy parts of the sea bed, *e.g.*, the flat-fishes, soles and flounders, and some of the bivalve shell-fish, are flattened, on the same principle that snow-shoes are made large and flat, *viz.*, in order to distribute the weight of the animal over as large an area as possible, and thus prevent it from sinking in.

The larva of the Echinids is called a **Pluteus** (easel-shaped) larva, because it has long straight appendages sticking out at angles with one another. These arms, as they are called, are supported by a provisional skeleton, and there are several pairs of them. When the adult *Echinus* is formed within, the arms atrophy (*i.e.* are absorbed). Some sea-urchins have the spines arranged so as to form an

external brood-pouch (*marsupium*), in which the eggs are hatched ; and, as happens among those star-fishes which are viviparous, in some of these forms

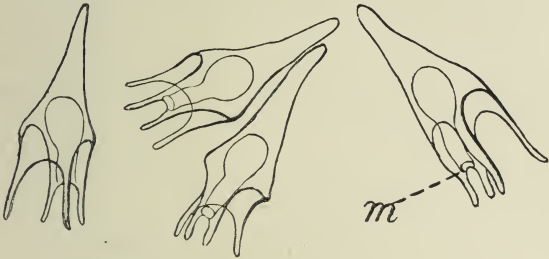


Fig. 45.—Pluteus larvæ (outline) of an Echinus, *E. microtuberculatus*: *m*, mouth. (Magnified.)

the young skip the larval stage and develop directly from the egg.

The HOLOTHUROIDEA, or Sea-cucumbers, are animals worm-like in appearance, in which the characteristic dermal skeleton of the Echinodermata is reduced to scattered spicules in a leathery body-wall. They have tentacles which belong to the water-vascular system ; but the tube-feet tend to degenerate, and in some forms are entirely wanting. Their symmetry tends towards the bilateral type, although the tentacles are radially arranged round the mouth ; the body is elongated. They are often nocturnal and predatory, and sometimes phosphorescent. The common Sea-cucumber is their representative in English seas.

CHAPTER V.

VERMES.

Animals more or less resembling in structure the Earthworm (see p. 132).

Classes.—PLATYHELMINTHES, or Flat-worms.

NEMATHELMINTHES, or Round-worms.

ANNELIDA, or Earthworm-like worms.

Sub-classes: CHÆTOPODA, GEPHYREA,
and HIRUDINEA.

ROTATORIA, or Wheel-bearing animals.

THE VERMES, or Worms, are the simplest kind of segmented animals (see p. 83). We have in this group the beginnings of the segmented type. All are bilateral: some of the lower forms are not segmented, and those that are segmented have the segments much alike, instead of being variously modified for different purposes. They have no legs.

It should, however, be stated that the differences between the lower and the higher worms are so important that some zoologists prefer to make the lowest class (*Platyhelminthes*) a separate group, under the name of **Platodes**. The group of Vermes is of great importance as affording a sort of centre, from which several other great groups seem to have branched off. This is indicated by the nature of their larval forms: for some worms have a ciliated larval form called a

trochosphere,¹ which may be compared (in its degree of development, not in its appearance or details of structure) with a medusa; and in the Echinoderms, Brachiopods, and Molluscs, larvæ, more or less resembling this, are also found. *Balanoglossus*, already named as a link between vertebrates and invertebrates, is a worm-like animal which has a larva of this kind, the special characters of which in some degree approach those of the larva of Echinoderms.

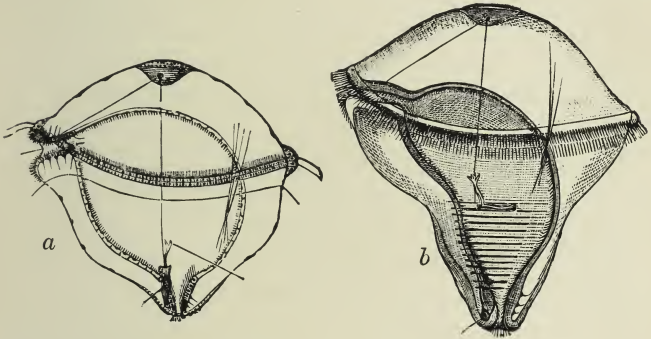


Fig. 46.—*a*, **Trochosphere Larva** of *Polygordius*, an annelid worm, showing ciliated bands, and internally the stomach with mouth to the left and excretory aperture below.

b, A later stage of development, showing the bilaterally symmetrical body of the worm, consisting of successive metameres, added on as an elongation of the trochosphere.

The group of Worms is so various, and so full of

¹ This kind of larva moves by means of its bands of cilia, which by their action whirl it about; hence the name trochosphere (wheel-ball). For a detailed description of one of the most important of the larval forms of worms (*Polygordius*, an Annelid), see Parker, "Lessons in Elementary Biology," Lesson xxvi.

puzzles, that it will be best merely to name the larger groups and refer to a few of the more commonly known forms.

The class PLATYHELMINTHES (worms with flattened body) includes the orders *Turbellaria*, *Trematoda*, *Cestoda*, and *Nemertina*. The first includes the *Dendrocæla* and the *Rhabdocæla*, mostly fresh-water forms that live by sucking the juices of other animals. *Microstomum* forms, by budding, what are apparently segments or metameres, though they often fall apart by transverse fission. It has been suggested that articulated or metameric animals, such as the higher worms (Annelids), and the Arthropods, have originated from worms of the lower types by the formation of a chain of buds like this (Fig. 46). The *Rhabdocæla* develop direct from the egg, the ciliated embryo being liable to be confused with *Infusoria*. The *Dendrocæla*, mostly marine forms, but some of them terrestrial, are very flat, and receive their name from the fact that the alimentary canal divides into multitudes of minute branches, like trees: these are to be noted as including the first *land* animals we have yet had to think of. They are only *half*-terrestrial, though, for they live in very damp places. Some marine forms have a larval stage. The *Trematodes* are parasites, and include the "flake" worm which lives in the bile-duct of the sheep's liver. It requires, however, two "hosts" for its development. The ciliated embryo gets into a water snail (*Limnæus truncatulus*), and there it enlarges, and develops into a sporocyst. The latter is a

sac-like body, which develops within itself from asexual germ-cells small creatures called *Rediæ*: these in turn similarly develop others with suckers and a tail, called *Cercariæ*. These get out of the snail, and swim about in water. Then they encyst, sticking to the grass, and get eaten by sheep, within which they assume the sexual worm form, the fertilized eggs of which again go through the same cycle. The *Cestoda* include the Tape-worm, *Tænia*, which presents a somewhat similar life-history, the young tapeworms being developed asexually out of a parent cyst contained in one animal, and attaining their full length and maturity when they get into another animal which has eaten the first one. The adult animal, owing to its parasitic existence, has assumed a special type of structure, being possessed of no alimentary canal.

The Nemertine worms, or *Rhynchocæla*, possess a larva called a pilidium, which is in some respects like that of some Echinoderms. These Nemertines have a proboscis (Gk. *προβοσκίς*, elephant's trunk; snout), which can be thrust out or drawn in, and is used for attacking their prey. It is provided with a sheath; a theory has been suggested that this sheath is the original form of the notochord of vertebrates (see pp. 76 and 78), and that the ancestors of vertebrates were accordingly a group allied to the Nemertines.

The Nematode Worms, class NEMATHELMINTHES, include parasitic worms, such as thread-worms and the *Trichina*, which causes an acute and often fatal disease.

The class ANNELIDA are worms with segmented bodies, a highly-developed nervous system, and a vascular system.

The sub-class CHÆTOPODA are remarkable for their



Fig. 47.

Fig. 47.—A group of tubes of one of the tubicolous worms, *Serpula contortuplicata*, showing head and gill-filaments of one worm.

Fig. 48 a and b.—Shell-like tubes of *Spirorbis*.



a



b

Fig. 48.

appendages, called cirri or parapodia. The order *Polychæta* have tentacles and tree-like gills (*branchiæ*); *Polygordius*, the larval form of which has been referred to on p. 179, is considered to be allied to them. The sub-order *Errantia* are free-swimming forms. The Sea-mouse is fairly common; it is a creature not much like a worm in shape, covered with long pur-

plish-black bristles, with a bronze iridescence. It has eyes, tentacles, and a proboscis which can be protruded. All the Errantia are carnivorous, and hunt for their food. The *Tubicolæ* (tube-dwellers), as their name implies, mostly secrete a house for themselves. They include some of the most familiar marine worms—*Terebella*, which builds itself a tube cemented of sand and shells; *Pectinaria*, so called from its comb-like gills, which builds a tube of grains of sand only; *Spirorbis*, which secretes the minute coiled tubes, like univalve shells, which are often seen attached to tangle and other seaweeds; the *Serpula*, which secretes larger snake-like tubes, found in multiple masses on shells and stones; *Sabella*, which is much larger, with a tube not so much twisted. The last two are very pretty objects when their heads, with their bright-coloured branchial filaments, are protruded from the tubes. *Arenicola*, the lob-worm, which burrows in sand, is nearly related to them; but the gills are not on the head, but further down the body. It has no tube. The *Oligochaeta*, another order of the Chætopoda, are familiarly represented by the common earthworm. The small delicate-looking worms found in mud are a nearly allied form, called *Nais*. The earthworm is the animal usually chosen for description as a type of the more highly developed members of the group Vermes (see p. 132). The body consists of a series of rings or segments. The mouth leads by a muscular pharynx to a well-differentiated alimentary canal, lying in a body-cavity. The

body-cavity is traversed by transverse partitions which divide it into a series of chambers. The nervous system consists of a double dorsal ganglion at the head, with connectives passing round the mouth, together with a double nerve-cord placed in the ventral or lower part of the body. Excretory organs are present, which are called nephridia (little kidneys) or segmental organs, and lie in pairs, opening to the surface on successive segments of the body. There is red blood, circulating in a system of longitudinal blood-vessels. The reproductive organs are bi-sexual, and somewhat complicated in structure. The earthworm has no free larval stage. For a description of the habits of the earthworm, the student should consult Darwin's work on the subject.

The sub-class GEPHYREA are a group of worms with very curious larvæ; *Sipunculus* is occasionally met with on our shores. The Leeches, HIRUDINEA or DISCOPHORA, have a sucking mouth-disc, with serrated jaws and no appendages. Some of the leeches make a sort of cocoon in which to lay their eggs, composed of albuminous material, which the young afterwards suck in for food. In other forms, the young suck this material directly from the mother, who carries them attached by their suckers. Some kinds are parasitic.

The ROTIFERS, or ROTATORIA (wheel-bearing animals), are placed in the group of Worms. The peculiar feature of the Rotifers is the wheel organ, a disc with revolving cilia, situated at the anterior end, by

means of which the animals swim. The sexes are distinct, and the males are much degraded in form, having the alimentary canal reduced to a useless rudiment: and in consequence of the great simplicity of their structure, they were formerly regarded as Infusoria. The Rotifers are fresh-water animals, and are commonly to be met with; they are of microscopic size. In dry weather they may be apparently quite desiccated, and yet return to life when placed in water.

CHAPTER VI.

ARTHROPODA.

Animals more or less resembling in structure the Lobster (type of the water-breathing Arthropoids), or the Cockroach (type of the air-breathing Arthropoids).

Classes.—CRUSTACEA, or Lobster-like animals.

Sub-classes: ENTOMOSTRACA and MALACOSTRACA.

ARACHNIDA, or Spider-like animals.

PROTOTRACHEATA; Peripatus.

MYRIOPODA, or Millipedes.

HEXAPODA, or true Insects.

} Tracheata.

THESE are bilateral segmented animals, with legs and segments which are modified for various purposes. The most apparent general characteristic is the presence in the adult of a hard, shell-like exoskeleton. There is a highly developed nervous system; and the higher forms are exceedingly highly organized and possessed of a great deal of intelligence. They receive their name (joint-footed) from their legs, which are necessarily attached by joints, because the animal is covered with a hard "shell."

The CRUSTACEA nearly all live in water, and breathe, where distinct breathing organs are developed, by gills.

The ENTOMOSTRACA (or crustacea with divided shells) are mostly fresh-water forms. They include the so-called water fleas. They make excellent microscopic

objects from their transparency : mounted specimens may be obtained from dealers in such things, and the student may find numerous forms for himself. Some undergo metamorphosis, the early larva being of the form called a *Nauplius*, having first been described under that name. *Cypris* is a genus whose fossil shells are found in many geological deposits. The Carp-lice are parasitic forms of Entomostraca.

The *Cirripedia*, or Barnacles, are an especially interesting order. These develop from a Nauplius larva (Fig. 49), and change into a higher form which is like a *Cypris*; it has antennæ, an unpaired eyespot and a pair of compound eyes beside, and a gland called a cement gland, at the head end. This larva fixes itself by the antennæ, being glued down by the secretion of the cement gland, loses its paired eyes, and lives for the remainder of its days standing on its head. Prof. Huxley says, it is "a Crustacean fixed by its head, and kicking the food into its mouth with its legs." The Long-necked Barnacles (*Lepas anatifera*, fig. 51, frontispiece) are common on wreckage; they have a coloured shell, china blue with a streak of orange at the edge of the valves, in texture like that of a mollusc, but composed of several plates, bilaterally arranged. From the appearance of this shell, the barnacles were formerly supposed to be molluscs. The "stalk" is a tough leathery structure, containing the cement gland and its duct, and in the adult the ovaries; it is flexible, and bends about with a slow movement and with

graceful curves when the animal is alive. The animal receives its name, *anatifera*, the goose-bearer, from the fact that an ancient superstition represented it as the offspring, and in turn the parent, of a wild goose. It would seem as if the forgotten poetic genius of a prior age, who invented this legend, had made some wild forecast of the facts of alternation of generations which have been already described in other forms. More common than the Long-necked Barnacle are the

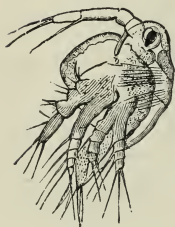


Fig. 49.

Fig. 49.—Free-swimming Nauplius larva of a barnacle (*Balanus*), magnified. (From Claus and Sedgwick.)

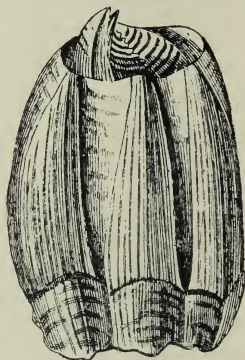


Fig. 50.

Fig. 50.—Shell of adult barnacle (*Balanus tintinnabulum*), sessile and fixed.

common sea-side barnacles or acorn-shells, *Balanus*, which cover the large stones of the shore near low tide mark. The shell is differently arranged; it has movable valves peeping out of a thick rim composed of several pieces joined together. In both, the legs form a group that reaches out and closes again exactly like a little hand.

The MALACOSTRACA consist of two groups, the *Thoracostraca*, which include the most highly organized of the Crustacea; and a lower group, the *Arthrocostraca*, which are distinguished from them by having the segments of the thorax (chest region) separate instead of fused, a fact which indicates a more primitive condition of the body. Among the *Arthrocostraca* may be mentioned the *Amphipoda*, which include the Sand-fleas, or Sand-hoppers, so common on the sea-shore. They have powerful jaws, and will gnaw through all sorts of things, including sheets left out to dry, when they get the chance. The body of the sand-hopper and its allies is laterally compressed. This is probably an arrangement for their hopping propensities, by which their sharp backs cut the air, as the keel of a ship cuts the water; for they do not jump forwards like jumping insects, nor backwards like lobsters, but arch their bodies and jump in any direction; their shape also serves another purpose, namely, to enable them to sidle under stones. An unfailing, however unintentional, trap for them, if their almost incredible hopping powers bring them up into a house near the sea-shore, is a tea-cup and saucer, with a little tea spilt in the saucer. You hear the tea-cup making seemingly spontaneous noises, and find that a "hopper" has mistaken the saucer for a wet stone, and insinuated itself under the cup, using its sharp back as a wedge. The task is quite easy for it, for these little crustacea possess, like beetles, an enormous strength for their size. These interesting creatures do not fail

to unite domestic virtue with athletic prowess, for all the tribe are noted for their care of their young. The Fresh-water Shrimp (*Gammarus*) has been watched sheltering its young under the edges of its appendages (flat plates called oostegites, forming a broad pouch in which the young are carried), as a hen does her chickens under her wings, when the water that contained the family was purposely disturbed. The wood-lice (*Oniscidæ*) are another familiar form, belonging to the *Isopods* (equal-footed). The English wood-lice belong to the genera *Oniscus*, *Porcellio*, and



Fig. 51.

Fig. 51.—A Woodlouse (*Oniscus murarius*).

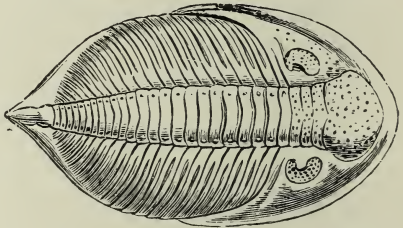


Fig. 52.

Fig. 52.—A Trilobite (*Asaphus candatus*).

Armadillo, and some of them can roll themselves up like a ball, if frightened. Like the sand-hoppers, they carry the young about in a pouch, formed of the modified edges of their appendages. They eat soft wood and roots, etc., and do great mischief in gardens and greenhouses. The fossil *trilobites* are believed to be related to them: they also had the habit of curling themselves into a ball. Little trace is found of anything but the dorsal shell of the body, and their nature is therefore not certain.

The higher crustacea are highly organized, possessing nearly as many different kinds of organs as can be named in vertebrates, although of course differing in their relative positions and arrangement. The lobster, for example, possesses a highly developed nervous system, with complex eyes and ears, and a corresponding degree of intelligence; gills for breathing; an alimentary canal consisting of gullet, stomach, and intestine, and supplemented by a paired ferment-producing gland called the liver; a paired excretory organ, the green gland; a complicated muscular system; a vascular system and heart, containing blood, with stellate, amœboid, colourless corpuscles; and complicated reproductive organs.

The higher forms of crustacea are distinguished by the extent to which successive segments are fused and modified. The anterior segments, including the head, form the *cephalothorax* (head and breastplate). The name of *Thoracostraca* (breastplate-shelled) has been accordingly given to them; the group is also called *Podophthalmata* (foot-eyed), because they are further characterized by having their eyes carried on stalks. The higher forms are included in the order *Decapoda*, of which the division *Macrura* (big-tails) includes the Lobsters, Cray-fishes, Shrimps, and Prawns; and the division *Brachyura* (short-tails), the Crabs, so called because in the adult the tail is greatly reduced: its segments are small, and are permanently tucked under and applied to the under side of the thorax. The Crabs and Lobsters have a larval form called a *Zoea*

(fig. 54). The hermit-crab (*Pagurus*) belongs to the *Macrura*, and has a soft tail; hence it has to live in the empty shell of a univalve. These crabs are very amusing. If two are put in the same basin of sea-water they instantly go for one another; the stronger will turn the other out of his shell, and try it on; but as the stronger is usually the bigger, he mostly leaves it for his own, and lets the original owner go back to it. Indeed, the fight seems to arise according to the principle enunciated by Sir Arthur Helps, that "Every

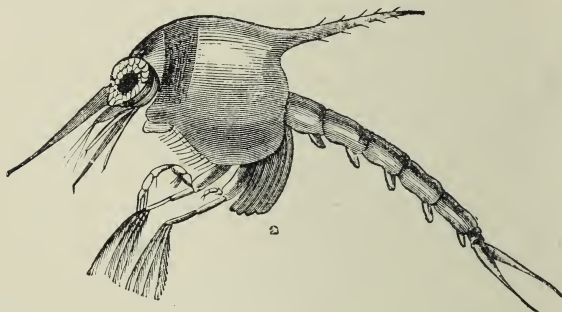


Fig. 54.—Zoea or larval stage of the common Shore Crab, *Carcinus Menas*.

man thinks every other man's bread-and-butter is nicer than his own," *i.e.* every hermit-crab thinks every other hermit-crab's shell is nicer than his own, until he has an opportunity to try it, and convince himself of the contrary. The fact is, that since a new shell is very necessary as the crab grows, and is not always immediately to be found, a new shell is the *summum bonum* of hermit-crab existence, and the belief that his own shell is too tight is a fixed idea.

I have put a handful of empty univalve shells, say a dozen or more, into a basin with a hermit-crab, and watched him try on every one of them, though they were all a misfit, and he had to go back to his own in the end. If you require to be convinced that in the matter of acquiring worldly goods crustacean nature and human nature are identical, study two or three hermit-crabs for a day; but remember to put them back in the sea afterwards.

The ARACHNIDA, or Spiders, are defined as "air-breathing Arthropoda with fused head and thorax, with two pairs of jaws, four pairs of walking legs, and no feet attached to abdomen." The Mites and Mock-scorpions are nearly related to them.

The *Acarina*, or Mites, are exceedingly simple animals; they have no heart or blood-vessels, and often no eyes, while the nervous system is reduced to one ganglion. Many of them are parasitic, and have a mouth adapted for sucking, called a **Rostrum**. Nearly every animal has its own special species of infesting mite. The ticks (*Ixodes*) are a kind of mite, but larger. The common Cheese-mite (*Tyroglyphus*) is a familiar example; it also lives on flour: others live on sugar, etc., and many on plants, which they soon destroy. There are also marine mites. The young of many kinds have at first only six legs, instead of eight. Some of the parasitic forms are curiously altered to suit their mode of life. A mite called *Demodex folliculorum* lives in the hair-follicles of animals and man: it has an elongated body and very short legs.

The little red mite called the harvest bug, and the itch insect, may be mentioned as other forms which attack man. Other mites produce galls on plants: these galls may be known from those produced by insects by the fact that they are *not closed*; but on turning up the leaf, you find that it is merely thickened and gathered up in a blister, to form the gall.

The various Mites, and some other forms, including *Pentastomum*, a degraded parasitic form which is found in the head of the dog, are sometimes classed together as *Lipobranchiata*, or Arthropods that have no gills.

The true Spiders have the body divided into two regions composed of fused segments: the thorax, which bears eight legs and is joined with the head, and the abdomen. They breathe with lungs, the openings to which are situated on the abdomen. The **spinnerets**, or glands which secrete the thread for the web, are placed at the end of the abdomen. There are a number of simple eyes, eight in most families, but six in others. A poison gland is placed in the first pair of claws (called the **chelicerae**). The different kinds of spiders construct their nests according to many different patterns. Some spiders, found in France and elsewhere, make a web in the earth, with a lid to it, furnished with a hinge; others make web lids to their nests; others make long tubular nests in the ground. The nest of the ordinary house-spider may be studied anywhere: if it be disturbed and broken from its attachments, the mother spider will take it up with her claws and carry it to

a place of safety. Probably the popular superstition, that it is unlucky to kill a spider, was invented by some one who had watched this proceeding. A home may easily be made for a spider out of a little box, and it makes a very interesting pet.

The *Scorpionidea* also have lungs; but they have the segments of the abdomen not fused, but single, the last six, diminished and elongated, forming a tail. Above this lies a round abdomen, also composed of distinct segments, and distinct from the thorax, which bears appendages. The *chelicerae* are developed into strong pincers; the poison gland, unlike that of the spider, is in the tail. The breathing organs, called **lung-books**, consist of chambers containing numbers of flat plates; though adapted to breathe air, they are considered to be comparable with the "gill-books" of **Limulus** (see below). There are several pairs of eyes.

The *Pseudoscorpionidea*, Mock-scorpions, or Book-Scorpions, are so called because they live in old books. They are minute mite-like creatures, with no tail and no sting. The common one, *Chelifer*, so called from its scorpion-like claws, has two eyes; some others have four: they breathe by *tracheae*, or tubes, like insects.

Limulus, the King-crab, is a creature from the Indian and Atlantic Seas which may be seen in most large aquaria, and which from the shape of its shell and tail gives one the general impression of a crab that has armed itself for war with an inverted pudding

basin and a skewer. This, with some fossil types which are related to it, forms a separate group, the *Xiphosura* or *Gigantostraca*, which used to be classed with the Crustaceans. Prof. Ray Lankester, however,

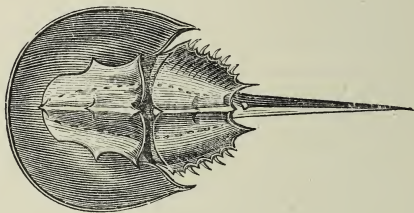


Fig. 55.—The King-crab (*Limulus moluccanus*).

has transferred it to a position near the Spiders, with which it is linked by the Scorpions, under the name of *Hæmatobranchia*. *Limulus* has two compound eyes, and two simple eyes.

The rest of the Arthropods are included under the name of TRACHEATA, because they breathe through tubes called tracheæ. These include, besides the insects, class HEXAPODA, also the Millipedes, class MYRIOPODA, and a class called PROTOTRACHEATA, which consists only of one genus, *Peripatus*. This name has been given to it because *Peripatus* is believed to resemble the archaic type from which the rest of the *Tracheata* have been derived. It has a distinct head, with one pair of antennæ and two eyes, and from fourteen to over thirty pairs of short legs, which differ from those of the Centipedes in having bifid

claws. There are a pair of excretory organs, called segmental organs, in each segment, a very worm-like feature, in which it differs from the type of the higher insects, which have coiled excretory tubes, called Malpighian tubes, attached to the posterior part of the intestine. It breathes by tracheæ.

The MYRIOPODA, or Millipedes, also have a distinct head, with one pair of antennæ; and all the many segments between it and the tail are much alike. The young sometimes undergo a kind of metamorphosis which might almost be rather called augmentation, for new segments are added constricted off from the hind one, until the animal is complete. Species belonging to the order *Chilopoda* have the body very flat; they have nippers near the mouth with poison glands, from which it easily may be understood that they are carnivorous. They are called Centipedes. The large and dangerous centipede of the East is called *Scolopendra*. There is a common English one which is yellow in colour, is long and very flat, and wriggles itself in peculiar wavy curves, moving stiffly in the plane in which it is flattened. This is *Geophilus*. It has no eyes, but moves its antennæ very rapidly about to gain impressions. It makes a nest in the ground, and the female sits on her eggs, coiling herself round them. The Geophili are phosphorescent, and not only so, but they leave a phosphorescent trail behind them; hence, Linnæus gave to one of them the specific name *electricæ*. There are several English brown centipedes with shorter bodies,

therefore much more active, and able to run with rapidity.

The *Chilognatha* are distinguished by having (except on a few anterior segments) two pairs of legs on each segment, and the body is not so flat as in the last order. These include the true millipedes, *Julus*: they live on roots. Some of them have small eyes (*ocelli*) aggregated together. The larger English species are considerably over an inch long; they are dark in colour, and shiny. *Julus pulchellus* is a very small one, destructive to bulbs and hothouse plants; it is of a pale colour, and blind. The *Glomeridæ* are short forms, with only a few segments, which curiously mimic the wood-lice in appearance.

The true Insects are called HEXAPODA, because they have only three pairs of legs in the adult form. Besides these they often have wings. Only the lower forms are developed straight from the egg; they are therefore called *Insecta ametabola*, insects which do not undergo change; the rest undergo metamorphoses, more or less complete in character. The Insects receive their name (cut in parts) from the fact that they are divided into two body-regions: the thorax, which has appendages, the legs; and the abdomen, which has no legs. These are separated by a very marked constriction; both have the segments completely fused. The head is separate from the thorax, and has appendages for biting, etc. Entomology, the study of insects, is derived from their Greek name, which is the same in meaning as the

Latin word Insect. The hard covering which is so remarkable a feature of the class is composed of **chitin**. This substance may be obtained by boiling insect wing-cases, etc., in dilute caustic soda, and afterwards washing successively with water, dilute acid, and boiling alcohol and ether. The coat of insects consists of this substance alone; that of crustacea is additionally hardened by calcareous matter. Most of the hard structures of invertebrates either consist of chitin or have a basis of chitin, and this is true of internal hard structures as well as of external ones. Chitin is indigestible by animal digestive juices; therefore, although whole orders of birds and mammalia live on insects, they are apt to disagree with animals not hereditarily accustomed to them; and the domestic cat, when she unluckily makes the blunder of classing herself with the Insectivora by eating the cockroaches that infest town kitchens, usually wastes and pines, and eventually succumbs.

It has been already mentioned that insects breathe by **Tracheæ**. These are hollow tubes with walls thickened by a spiral ring of chitin, which penetrate to all the organs of the insect's body, carrying a supply of air, which gets into them through holes called **Stigmata**, which are situated in a row down the sides of the body. Hence it is that land insects are drowned without being completely immersed, and while the head is not covered with water. The necessity is not, as with us, to keep the head above water but the sides, which is impossible as soon as the

wings become draggled. Some flying insects have dilated vesicles on the tracheæ, which make the insect lighter, since they are filled with air, and thus help it to sustain itself in the air. Some of the insect

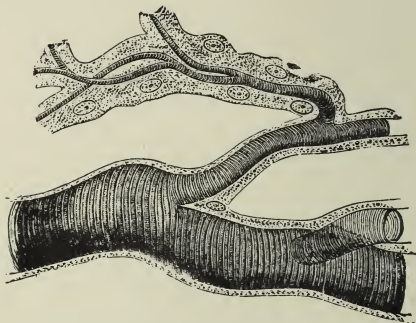


Fig. 56.—Tracheæ of an insect, magnified. (From Claus and Sedgwick, after Leydig.)

larvæ that live in water have leaf-like appendages, called tracheal gills, for respiring water (larvæ of May-flies and Spring-flies); others have respiratory plates in the rectum (Dragon-fly).

The *Thysanura* have been divided into the *Collembola*, or Spring-tails, the *Campodidæ*, and the *Lepismidæ*, or Bristle-tails. They infest greenhouse frames, and the former have their tails tucked underneath when at rest. *Lepisma*, so called from its minute scales, which give it a silvery-bronze appearance, does not jump, but *Machilis* does, a larger kind which lives near the sea-shore. The latter, in my experience, has a predilection for old boots which have been soaked

with sea-water, a refuge from which I have turned it out in dozens. It has three *setæ*¹ on the tail, and two long antennæ on the head, and these are, respectively, nearly as long as the insect, so that it

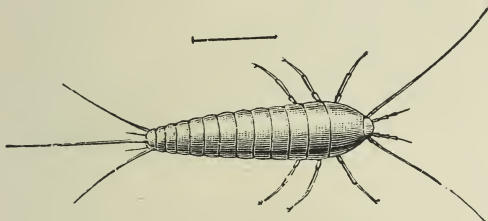


Fig. 57.—*Lepisma saccharina*, enlarged.

seems a most fragile creature to risk its long leaps. The *Thysanura* are very simple forms; some have no tracheæ at all, and these, if present, are comparatively little branched. They develop direct from the egg.

The *Orthoptera*, which have two pairs of wings, usually unequal, and biting jaws, undergo an incomplete metamorphosis; they include Cockroaches, Earwigs, Grasshoppers, Locusts, and Crickets. The Praying Mantis, so called from the way it folds its front legs while watching its prey, and the Leaf Insect of the East Indies, which has wings exactly like green leaves,—a case of “protective mimicry,”—also belong to this group. The young Cockroach has no wings;² the student should obtain specimens of the male and female cockroach, and of the young, and note the dif-

¹ Bristles. ² Those of the female are rudimentary.

ferences. The Mole-cricket, *Gryllotalpa vulgaris*, is so called because it digs subterranean passages to its



Fig. 58.—Mole-cricket (*Gryllotalpa vulgaris*) and Nest.

nest. This and the other *Gryllidæ* destroy roots and do much mischief.



Fig. 59.—House-cricket (*Gryllus domesticus*).

A sub-order is called *Pseudo-neuroptera*, because

the insects have veined wings that look like those of the *Neuroptera*; but the two pairs are alike, and they cannot be folded. The White Ants, or *Termites*, belong to this sub-order. They are the Romans of the insect world; they build cities and construct roads and causeways as they march. They are polymorphous; there are worker ants and soldier ants, which do not develop sexual organs; winged individuals, which are the males, and in each ant-hill one female, or queen. They eat most organic substances; and the part they play in the scheme of nature is to clear away the old vegetation of dense tropical forests. The May-flies (*Ephemeridæ*, i.e., Day-flies) and Dragon-flies belong to the same group.

The true *Neuroptera*, which have a complete metamorphosis, include the curious ant-lion of Southern Europe, the larva of which, a grub-like creature, but with hairy legs, digs a pit in sand, and lies in wait at the bottom for ants to fall in; and the Caddis-flies (*Phryganea*), also called Spring-flies, whose larva, the Caddis-worm, builds itself a protective tube of sand and shells.

The *Hemiptera* are sucking insects, some forms of which have four wings, some two, and some none. The lice are wingless forms (*Aptera*), while the Cochineal insect and its allies have wings in the male. The *Aphidæ*, or plant-lice, are a most interesting group. They are peculiar in exhibiting *parthenogenesis*, or asexual reproduction. The males and females are produced mostly in the autumn, and the

eggs give rise to viviparous Aphides, which reproduce themselves asexually for numbers of generations, from unfertilized germs which are called *Pseudova*. These viviparous Aphides have wings; the true egg-bearing females have no wings, but the males are winged. Parthenogenesis sometimes occurs among other insects, but not so markedly as in the aphides. These creatures, which are also called green-flies, suck the juices of the plants they infest. They have a peculiar secretion of a sweet liquid, called honey-dew, which is secreted in tubes which open on the dorsal side of the last segment but one. Ants are very fond of this, which they suck from the aphides; they even keep them in their ant-hills for the sake of it, so that the aphid has been called the ant's cow. Among the higher forms classed as Hemiptera are the *Cicadæ* (Grasshoppers of classical writers), and the little green insect that covers plants with spots of foam in spring; it is the larva of *Aphrophora* (the foam-bearer), one of the *Cicadellidæ*.

The *Diptera* are suctorial insects which have the front wings membranous, and the back wings represented only by small knobs or stalks, the nature of which was long a matter of dispute. The Sheep-ticks, House-flies, and Blow-flies, the Gnats, and Breeze-flies belong here; also the Fleas, which have the aborted wings represented by lateral plates. The Crane-fly has a larva called the Wire-worm, which lives on roots, and is very destructive to crops.

The *Lepidoptera*, or Butterflies, are well known by

their curved sucker or proboscis and four scaly wings. The sucker is formed by the modification and union of the first pair of appendages, called maxillæ, while the other appendages of the mouth are but slightly developed: the butterflies are thus adapted for their mode of feeding, which consists in sucking honey (see fig. 61). They present the typically complete meta-

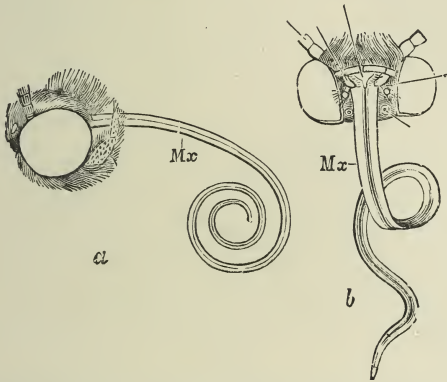


Fig. 60.—Suctorial proboscis of a butterfly, formed by the junction of the maxillæ (*Mx*). (From Claus and Sedgwick, after Savigny.)

morphosis of insects. The cocoon-spinners (*Bombycina*) include the Silkworm. Some of the spinners are social, and build a nest in common, as do also the caterpillars of some moths, *e.g.* Little Ermine-Moth (*Yponomeuta*), Brown-tail Moth, etc. The social forms would seem to have the germ of that colonial instinct which produces such remarkable results among the ants and bees. In the Processional Caterpillars of Southern Europe (*Cnethocampa pro-*

cessionea) the caterpillars march in order, first some in single file, then double, then in threes, fours, fives, and so on, and proceed till the leaders set to



Fig. 61.—Humming-bird Hawk-moth (*Macroglossa stellatarum*), sucking honey from the Trumpet Honeysuckle.

work to build a nest, in which they all join, producing one which is nearly two feet long and several inches in diameter.

The *Coleoptera*, or Beetles, have biting mouths, and the front wings converted into horny coverings (wing-cases) for the transparent under wings. They also go through a complete metamorphosis. The Ladybirds (*Coccinellidæ*) are among the most useful of English insects, for their larvæ eat aphides. The fate of the

hop season in Kent often depends on the arrival or non-arrival of the Ladybirds. *Anobium*, one of the *Xylophaga*, is familiar as the Death-watch of popular superstition. The noise, which is exactly like the ticking of a watch, is the call of the creature to its mate, heard constantly in old houses in warm weather. The larvæ are exceedingly destructive to wood, in which they bore holes. The beetle has been said to receive its name from its habit of "shamming dead" when caught, for it rolls over with its legs curled up; but many beetles do the same. More probably the name is derived from the superstitions about the insect. The Cockchafer (*Melolontha vulgaris*) is the adult of a larva very destructive to crops. It burrows in the ground and eats roots, and takes three years to attain maturity.

The *Hymenoptera* include the Gall-wasps (*Cynips*), the Ichneumon Wasps, and the true Ants, as well as the Wasps and Bees. The Gall-insects puncture plant tissues with their ovipositor (egg-placer), and inject an acrid secretion, at the same time laying their eggs; the tissues swell up and produce a gall, in which the larvæ are sheltered till their maturity. The commonest English kinds are the Gall-insect of the oak and Gall-insect of the rose, producing respectively what are known as "oak-apples," and the pretty moss-like red and green galls often seen on wild rose-bushes. The insects (Breeze-flies) which produce galls on cattle are *Diptera*, as has already been stated.

The Ichneumons lay their eggs in the bodies of

many kinds of insect, especially caterpillars; the larvæ feed on them, and become pupæ in the body of their host after they have killed it.

The Ants, *Formicidæ*, like the White Ants, live in communities. The “workers” are wingless imperfect females, and there are sometimes soldiers also, besides the winged males. The complete females also have wings at the pairing time, but lose them afterwards. The industry, so much admired by Solomon, is not

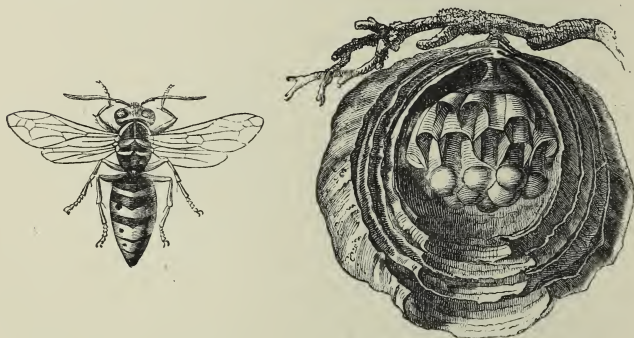


Fig. 62. – Wasp (*Vespa vulgaris*), and nest cut open.

the only proof of the intelligence of the Ant; on the contrary, some (the red ants) make slaves of others (the black ones), and are very warlike in disposition, but very lazy, making the slaves do all the work. As already mentioned, they keep aphides for cows. The ants have an acrid secretion, called formic acid, which is a protection against their enemies. Many beetles produce a similar fluid when frightened or annoyed.

The Wasps and Bees differ from the Ants in having

their workers winged. Some are solitary, and some social. The Wasps make their nests, not of wax, but of gnawed wood, made into a material like very thin paper. The Wasps provide their larvæ with honey and with insects; the Bees provide theirs with honey and "beebread," a mixture made of the pollen of flowers.

The Humble Bee (*Bombus terrestris*) makes its nest in the ground, and does not produce a "comb." It piles up masses of pollen, which the enclosed grubs mould into oval hollow cells. It has been stated that the old bees liberate them, when they are mature, by removing the top of each cell. The empty cells are afterwards used to store honey in.



Fig. 63.—Nest and ce'ls of Humble Bee (*Bombus terrestris*).

CHAPTER VII.

MOLLUSCA.

Animals more or less resembling in structure the Fresh-water Mussel (type of the bivalve Molluscs) or the Snail (type of the univalve Molluscs).

Classes.—LAMELLIBRANCHIATA or CONCHIFERA (bivalves), animals like the Fresh-water Mussel.

GASTEROPODA (univalves), animals like Snails and Winkles.

CEPHALOPODA, or Cuttle-fishes.

THE MOLLUSCA (soft-bodied animals), or shell-fish, are usually developed from a **trochosphere**, like that of some worms, which afterwards changes into a second larval form, called a **veliger** larva, because it moves by means of a ciliated fold, called the **velum**¹; it has a shell-gland to begin the secretion of the future shell. The molluscs usually have a “**shell**” in some form or other, secreted by the outer layer of the body, and crawl by means of the “**foot**,” a muscular expansion which is well seen in the snail. Their nervous system consists of a paired cerebral ganglion, joined by connectives with several other pairs of ganglia:

¹ The velum is formed out of the anterior and ciliated portion of the trochosphere. It is believed to be homologous with the “wheel-bearing” ciliated disc of rotifers. In the adult mollusc, it becomes converted into prominences surrounding the mouth which are called the buccal lobes.

there are sense-organs, usually eyes, ears, and sometimes tactile organs. The aquatic forms breathe by gills, the terrestrial forms by lungs. The alimentary canal is distinguished into throat, stomach, intestine, and rectum: kidneys, comparable with the segmental organs of worms, are always present, and a liver usually. The blood system is not completely closed, the vessels being in communication with "sinuses," *i.e.* irregular spaces containing blood; but there is always a heart.

The true Mollusca consist of three classes—the

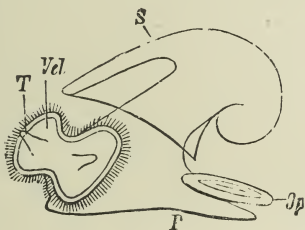


Fig. 64.—Veliger larva of a *Gastropod* mollusc: *S*, shell; *P*, foot; *Vel.*, velum; *T*, tentacles; *Op.*, operculum, for the closure of the shell opening,

LAMELLIBRANCHIATA, GASTEROPODA, and CEPHALOPODA. The Pteropoda, nearly related to the Gastropods, are sometimes separated from them to form a fourth class.

The Lamellibranchs (mollusca which bear gills in the form of plates), also called *Conchifera*, and Bivalve Shell-fish, are without a definite head. Their shells are placed to right and left of the body (not to back and front, as are those of the Brachiopoda), and are joined by an elastic hinge, and by adductor muscles.

The flat gill-plates are very characteristic of the class. The shell is lined by a loose muscular flap, covered with epidermis, called the **mantle**. The absence of a head is doubtless correlated with the presence of a shell.

Two orders were formerly distinguished in this group, the *Asiphonia* and the *Siphoniata*, classed according to the presence or absence of conspicuous siphons, tubes formed by a posterior elongation of the mantle, of which the lower is the "branchial siphon," and draws in fluid, and the upper is the "cloacal siphon," which expels it. The shell of the *Asiphonia* has an even "pallial line," as the mark is called, which is traced by the line where the mantle is fastened to the shell. There is never more than a rudiment of the siphonal structure, while in many of the shells of the other order the long retractile siphons leave a wavy mark on the mantle line. The longest siphons belong to forms that either burrow or lie in sand; and altogether the existence of the siphons seems to be a provision adapted for that mode of life, the *Asiphonia* being for the most part adapted to live among stones rather than on sand, fixing themselves by one valve, like the oysters, or mooring themselves to stones by secreted threads (called **byssus**) like the mussels, etc. This division includes the oysters, which have one valve attached, and therefore always lie on one side, the left, which is the deepest. The Scallops (*Pecten*) are the showiest of English bivalves. They receive both their names from the fluted pattern

of the shell; the latter has “ears” or flat expansions on each side of the hinge. They are sometimes called “sea butterflies,”¹ from the appearance of the coloured valves when they move; this they

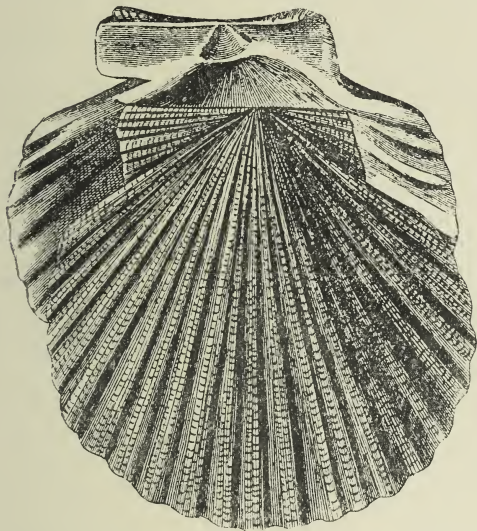


Fig. 65.—The Scallop Shell, *Pecten opercularis*, with ears of the two valves differently shaped.

do by a sudden hop that carries them some distance, and is accomplished by the sudden opening and closing of the shell. Like the oyster, they have one valve deeper than the other. The largest kind, *Pecten maximus*, is as large as a large oyster: *P. opercularis* is

¹ This name, however, belongs properly to the Pteropods.

one of the commonest and the most brightly coloured.

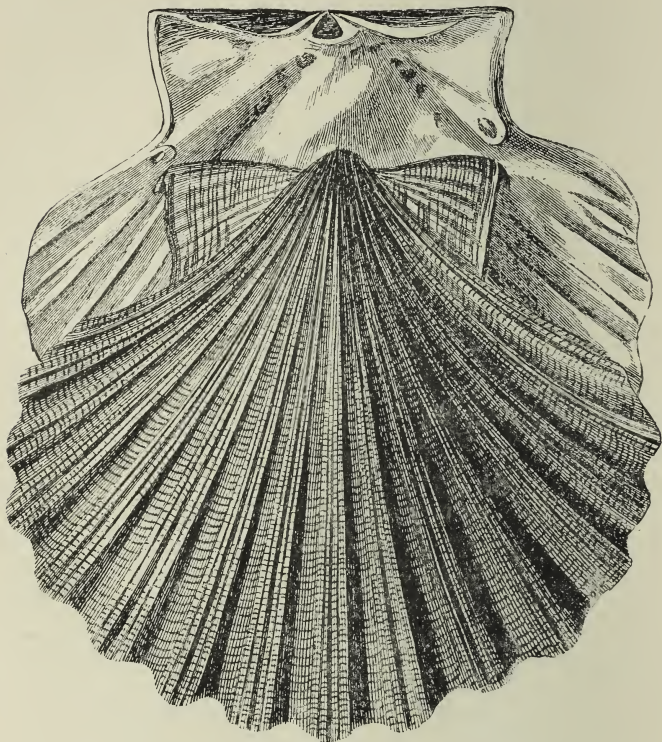


Fig. 66.—*Pecten Jacobæus*, the Pilgrim's Scallop Shell, formerly worn as a badge by travellers who had visited Palestine.

The *Pectens* are remarkable for their numerous eyes, which are situated on the mantle.

The *Siphoniata* are divided into two groups, the

Integro-pallialia (*Integri pallia*), with short siphons, and even pallial line; and the *Sinupallialia*, in which the siphons are long and retractile, and the pallial line bears a deep indentation corresponding with

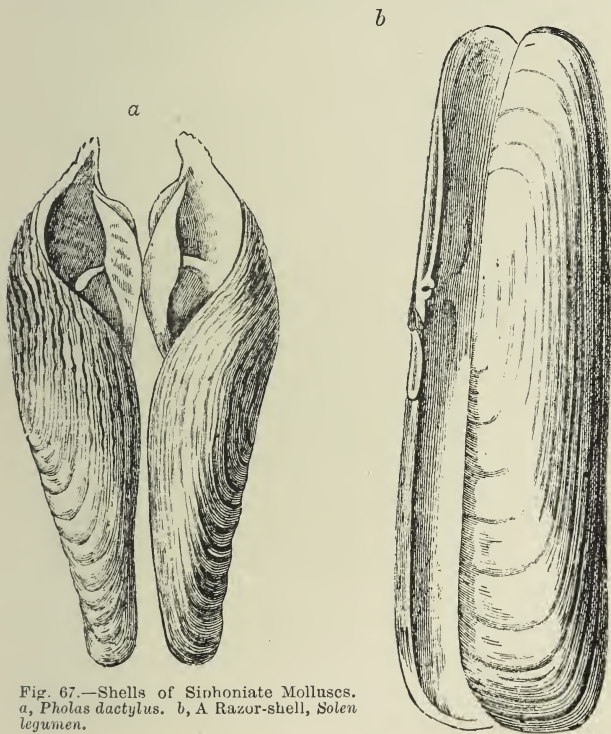


Fig. 67.—Shells of Siphoniate Molluscs.
a, *Pholas dactylus*. *b*, A Razor-shell, *Solen legumen*.

their site. One of the most curious of these is the *Pholas dactylus*, which bores itself a burrow in soft rocks by using the edge of the shell, assisted by

the foot, and the anterior edge of the mantle. The *Teredo*, or Ship-worm, which burrows in timber, belongs to the same family; it is much elongated and modified in shape, to meet the requirements of its mode of existence. Many of the Siphoniata, for

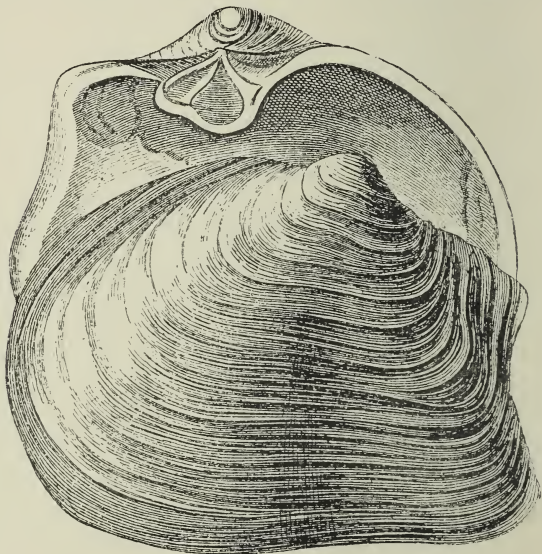


Fig. 68.—Shell of a Siphoniata Mollusc, the Gaper Shell (*Mya truncata*), so called on account of the open end of the shell, which admits the large siphon.

example the Razor-shell and the Gaper, make a deep vertical burrow in the sand, and push their long siphons up to the surface to breathe.

A different classification of the Lamellibranchiata is founded on the nature of the adductor muscles, which draw the shell together, and leave marks on

its inner surface. The oyster, lima, and scallop (*Asiphonia*) have but one adductor muscle, and are

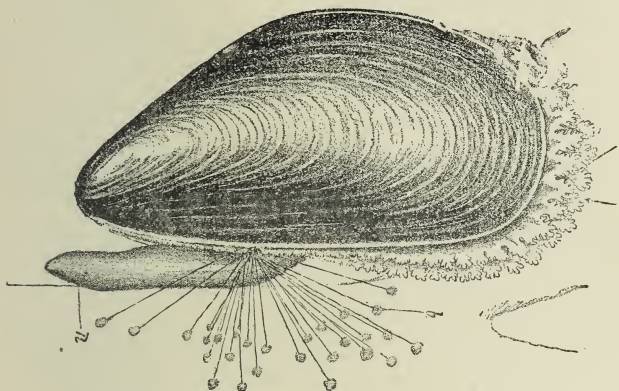


Fig. 69.—The Sea Mussel, *Mytilus edulis*, showing the foot giving rise to byssus threads, and the mantle fringed with gills.

called *Monomya*; the sea-mussels (*Asiphonia*) have

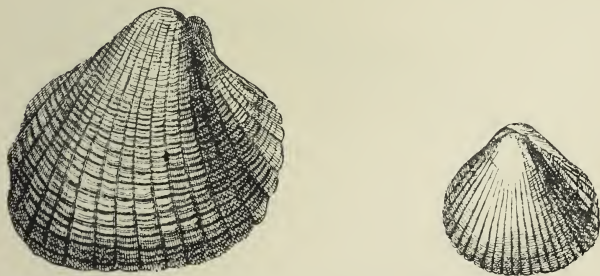


Fig. 70.—Shell of the common Cockle, *Cardium edule*.

two, and because the posterior is larger than the anterior they are called *Heteromya*; while the *Isomya*,

with two equal adductor muscles, include the *Sinupallia* and also the cockles and the fresh-water mussels

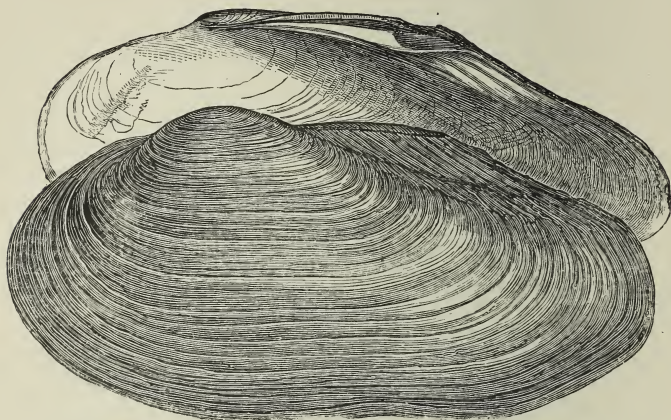


Fig. 71.—Shell of the Fresh-water Mussel, *Anodonta cygnea*.

Anodonta and *Unio*, so abundant in our streams. The

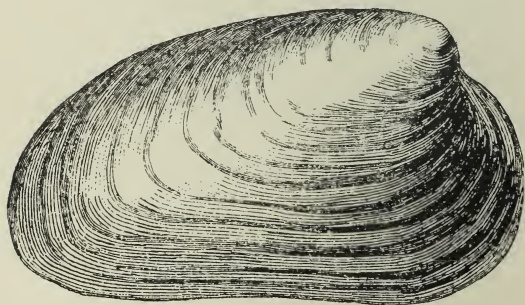


Fig. 72.—Shell of the River Mussel, *Unio litoralis*.

latter is the source of small seed-pearls, which in the

earliest historic times afforded profitable fisheries. The former receives its name from the absence of interlocking teeth on the hinge of the shell, of which one or more are usually present in other bivalves.

The *Scaphopoda* have been regarded by some as a group linking the Bivalves and the higher Mollusca. They develop from a larval stage which is in many respects very similar to that of other Mollusca, but the

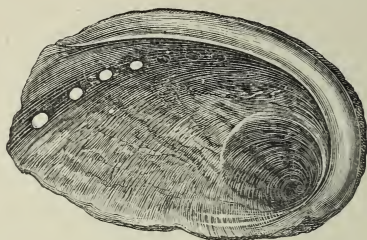


Fig. 73.—The Tusk-shell, *Dentalium incrassatum*.

shell becomes tubular. The *Dentalium*, or 'Tusk-shell', may be found occasionally on English shores: it is exactly like an elephant's tusk in shape, and perforated at the narrow end. It is more common on the American coast of the Atlantic, where it is known as the tooth-snail. It resembles the Gasteropoda in possessing an odontophore. It has otocysts, but no eyes. Its structure is adapted for its habit of burrowing in sand.

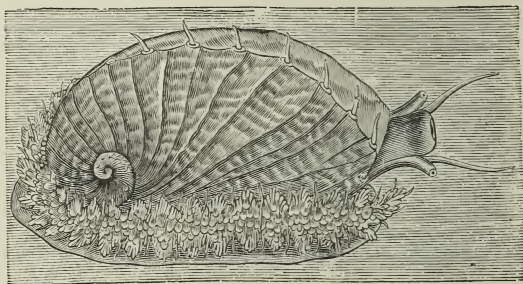
The GASTEROPODA are animals all more or less resembling the snails, and the Garden Snail (*Helix aspersa*, sometimes called the Tortoise-shell Snail, on account of the markings on the shell) is usually taken as a type of the class. It belongs to the Land Snails or *Pulmonata* (snails with lungs), and is adapted for breathing air; but the majority of the class live in the sea or in ponds and rivers, and are adapted for breathing water,

possessing gills instead of lungs. The Gasteropoda have a head, usually possessing paired tentacles: they



1.

crawl along the ground by means of their foot, and they have, as a rule, both otocysts and eyes. They have a tongue which is armed with teeth, and serves them



2.

Fig. 74.—The Sea-Ear, *Haliotis tuberculata*: 1, Empty shell; 2, Living animal crawling on its broad foot.

to grate away their food. This tongue is called the tongue-ribbon, or **odontophore** (tooth-carrier), and its pattern varies so much in the different groups of the class, that it has been sometimes made a basis

of classification. It is very common to find the halves of bivalve shells with a neat little round hole in them. This hole is the work of the odontophore of some carnivorous gasteropod. It will usually be found not far from the hinge, or in the neighbourhood of the adductor muscle of the bivalve; the shell opens wide when this is cut, leaving its tenant an easy prey.

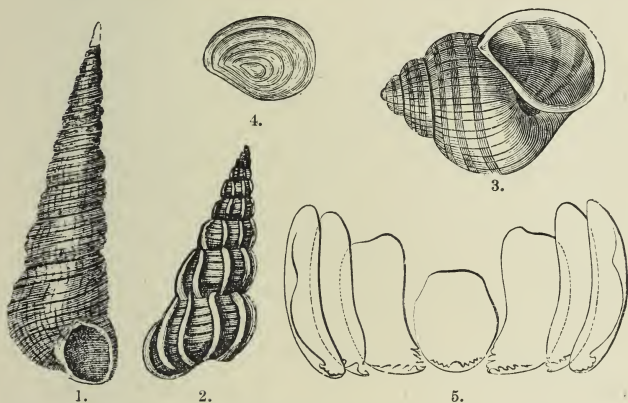


Fig. 75.—Examples of Holostomatous Gasteropods. 1, The Wimble Shell, *Turritella terebra*; 2, A Wentle-trap, *Scaloria similis*; 3, The River Snail, *Paludina vivipara*; 4, Its operculum, with concentric markings; 5, One horizontal row of teeth from its odontophore, magnified.

The shell of a gasteropod is usually spiral, but in a few cases it is flat, as in the common Limpet, or nearly so, as in the Sea Ear.

It is usually considered that the carnivorous species of the *Gasteropoda* may be known by a notch at the back of the shell; and according to the presence or absence of this notch, the *Gasteropoda* have been classi-

fied respectively as *Siphonostomata* (siphon-mouthed) and *Holostomata* (plain-mouthed). The notch is a feature which is only *indirectly* associated with the nature of the animal's food, since the siphon for which it provides room is a fold of the mantle which is respiratory in function. The association of the notch with the distinction in food habits is not quite invariable, but for the shell-collector the classification is a very convenient one. The student should note that the small end of the spiral is of course the posterior end of the shell: in placing shells in a cabinet, therefore, the elongated shells, such as olives and harps, if placed, as they often are, with the small end away from the spectator, are turned the reverse way from the snail shells and other flattened kinds, which are seen to the best advantage by turning the small end towards the spectator; while in all cases it must be remembered that the axis of the spiral of the shell is necessarily at an angle with the direction of the living animal in crawling. Many of the *Gasteropoda* have a stopper to close the shell with, when the animal retires inside. This stopper is called the **operculum** (lid). Some of these stoppers are calcareous, others horny: they exhibit in many cases a spiral mark corresponding with the gradual increase in size necessary as the mouth of the shell widens, or in other cases concentric marks, or complications of both.

In some kinds, the shell undergoes considerable modification in its adult form. When it ceases to increase in the length of its whorl, the lip may become

thickened, expanded, and ornamented, as in the Wing-shell (*Strombus*) of the West Indies; or, the interior of the shell may be also modified by the removal of part of the material of the old whorls inside, as happens in the cowries. In such forms, some care is required to identify the younger shells as of the same species with

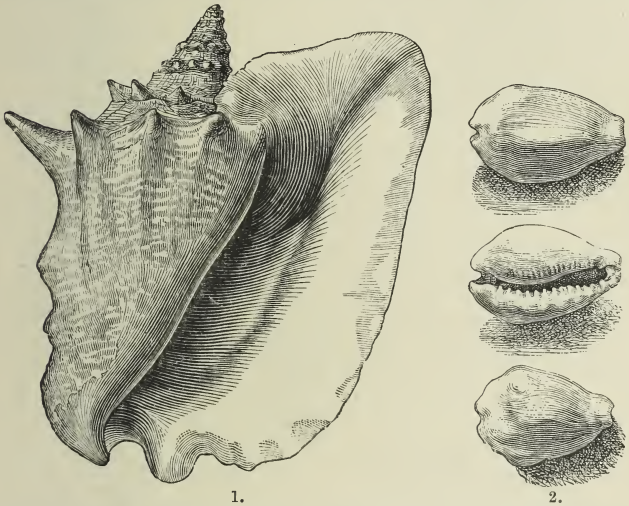


Fig. 76.—Shells of Siphonostomatous Gastropods. 1, The Fountain-shell, *Strombus gigas*, one-third the natural size; 2, The Money-cowry, *Cypræa moneta*, natural size.

the older ones. The increase of the width of the whorl, in some kinds, takes place more quickly in the female, so that the shell is wider in form. In these cases care is also required to identify the two forms as belonging to one species.

In some shells the exterior is ornamented with

spikes and spines, which serve at once for ornament and defence; a striking instance is the Venus' Comb, *Murex tenuispina*.

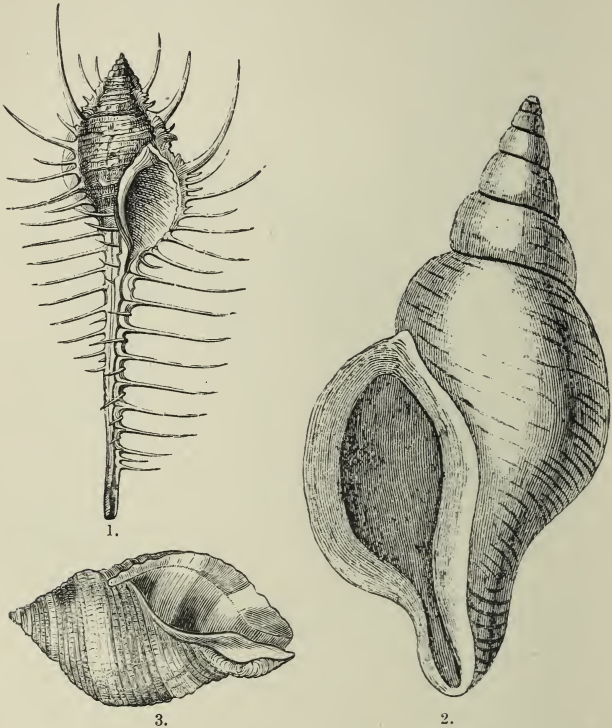


Fig. 77.—Shells of Siphonostomatous Gasteropods. 1, Venus' Comb, *Murex tenuispina*; 2, Sinistral variety of the Spindle-shell, *Fusus contrarius*; 3, The small Whelk or Purple, *Purpura lapillus*.

The spiral of the shell is occasionally found to be reversed, and in some genera it is always so. These

reversed shells are spoken of as **sinistral** (left-handed), because the spiral, when traced up towards its commencement, turns from the right towards the left. An instance is afforded by the Spindle-shell (*Fusus antiquus*), the reversed variety of which has received the name of *Fusus contrarius*. Sinistral shells occur also among the Cephalopoda (see fig. 78, p. 227).

The eggs of the univalve molluscs are often covered with a leathery egg-shell. The eggs of the large Whelk (*Buccinum*) which form large cellular masses, and those of the small Whelk (*Purpura*), which are egg-shaped and attached by the thin end to stones, etc., are both common objects of the shore.

The GASTEROPODA include the *Prosobranchiata*, with gills in front of the heart, an order which contains the majority of marine univalves, and includes all those which have been already mentioned; the *Heteropoda*, deep-sea forms with a small rudimentary shell; the *Pulmonata*, or Snails; and the *Opisthobranchiata*, or Sea-snails. The latter include a number of shell-less marine forms, and also the "bubble-shells," of which several are found on our shores. The *Placophora*, sometimes classed with the *Prosobranchiata*, are a primitive form belonging to the Gasteropod: one representative, *Chiton*, may be found adhering to rocks. It has a series of eight calcareous plates situated down the back. It possesses a well-developed odontophore.

The above is the old-fashioned classification of the Gasteropoda. The classification framed by Ray Lankester is founded on the amount of twisting undergone by the animal, and especially by its nervous system, in consequence of the presence of the shell.

The *Pteropoda* (wing-footed molluscs) receive their name from the wing-like expansions of the foot (*epipodia*). They are animals that float, anterior end uppermost, near the surface of the water, and are sometimes called sea-butterflies from the pretty appearance of their "wings." The body is straight, or nearly so. Some have a shell (*Thecosomata*), while others are without (*Gymnosomata*). The Pteropods are sometimes classed with the Gasteropods, but are included with the Cephalopods by Lankester.

The CEPHALOPODA are the most highly developed of the Mollusca. They have a distinct head, with a circle of sucker-bearing arms round the mouth, which represent the anterior part of the "foot" of other Mollusca, while the rest of the foot is modified into a tubular form called the **funnel**, which serves as an excretory and exhalant siphon. The nervous system is highly developed, and there are very large eyes. The order *Tetrabranchiata* attained its greatest development in past times, and is nearly extinct: while the fossil genera are many and large, including *Orthoceras*, *Goniatites*, *Ammonites*, *Ceratites*, *Turrilites*, etc., there is only one living genus, the *Nautilus*. (This nautilus is the Pearly Nautilus: the Paper Nautilus belongs to the next

group.) In this order there are four gills and

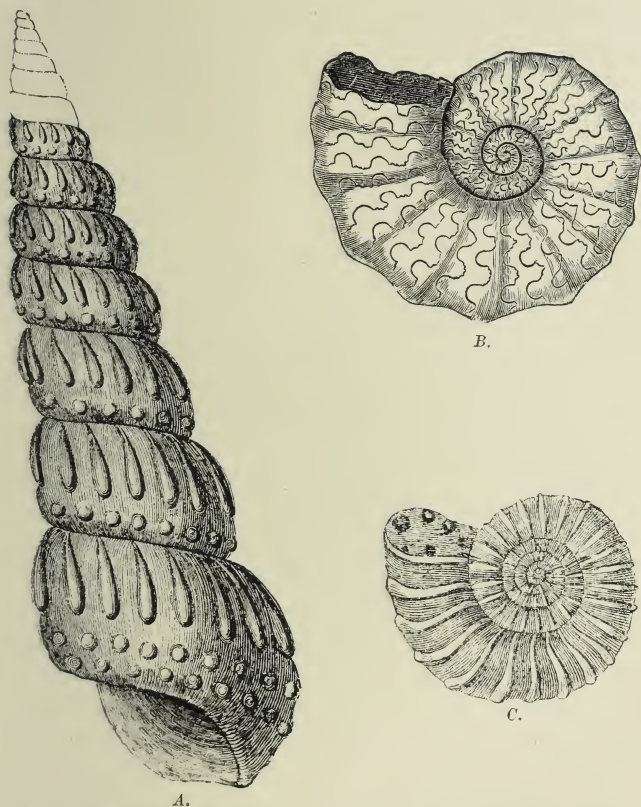


Fig. 78.—Shells of fossil forms of the Tetrabranchiate Cephalopods. The exterior markings of the shells correspond with the position of the successive air-chambers. *A*, *Turritites costatus*, with reversed spiral. *B*, *Ceratites nodosus*. *C*, *Ammonites planicostatus*.

numerous arms without suckers, called tentacles, and

the shell is external. The Pearly Nautilus has a spiral shell which is alike on both sides, the outside edge of the coil being occupied by the posterior surface of the animal, with the funnel, while the head lies next the coiled whorl: the animal in the live state therefore carries this shell standing on its edge, and the shell is straight, *i.e.* bilaterally symmetrical on each side of the plane in which it is coiled, instead of having a twist, as the shell of the Gasteropod mollusc has. Some of the extinct genera, however, have a shell of the ordinary spiral type, but sinistral (fig. 78A). The shell is divided into chambers, successively partitioned off by walls of shell, called **septa**. The animal only lives in the outer chamber, outside of the last-formed septum. The use of these empty chambers is to enable the animal to float on the surface of the sea. There is a small hole in the middle of each septum, called the **siphuncle**; through this hole passes a thin tube of flesh which connects all the successive chambers. By means of this the chambers can be filled with air.

The *Dibranchiata* have two gills and eight or ten arms, which are arranged round the mouth, and are provided with suckers. There are two sub-orders; the *Decapoda* include the common Cuttle-fish (*Sepia*) and also the fossil form called *Belemnites*: the *Octopoda* include the *Octopus*, or Devil-fish, and the Paper Nautilus, *Argonauta Argo*, so called from its appearance when floating on the sea. The "bone" of the Cuttle-fish is of cartilage, strengthened by calcareous additions: it is not present in the Octopoda.

The female of the Paper Nautilus has the well-known shell, but the male is without. The shell is simple, not chambered as in the Pearly Nautilus, though an



Fig. 79.—Pearly Nautilus (*N. pompilius*), a surviving form of Tetrabranchiate Cephalopod; shown in section, to exhibit the air-chambers of the shell.

allied species has chambers. The male is much like an *Octopus*. Like all the male Cuttle-fishes, it has one of its arms converted into a sexual organ, which is called a hectocotylus. In the Paper Nautilus, and some other forms, this breaks off, and is left in the shell of the female.

Some of the Cuttle-fish are phosphorescent in the dark. Some have an arrangement of pigment cells, called **chromatophores**, in the skin, by the alteration of the shape and shade of which they change colour. Many animals have something similar, *e.g.* the chameleon. In the Cuttle-fishes, the nerves which govern the chromatophores are connected with the optic ganglion. It should be added that the Cephalopoda, like the Gasteropoda, possess a lingual ribbon armed with teeth.

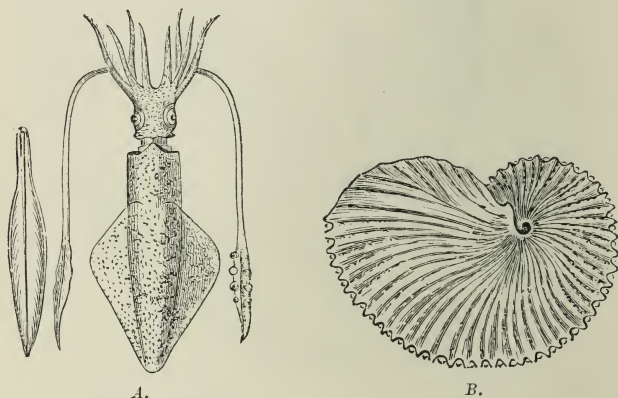


Fig. 80.—Dibranchiate Cephalopods. *A*, A Decapod Cuttle-fish, the Squid (*Loligo vulgaris*), and its bone. *B*, Shell of the female of the Paper Nautilus (*Argonauta argo*).

CHAPTER VIII.

MOLLUSCOIDA.

Animals more or less resembling in structure either the Sea-Mat (type of the Colonial Molluscoida) or the Lamp-shells.

Classes.—POLYZOA, or Moss-corals.
BRACHIOPODA, or Lamp-shells.

THESE are a group formerly classed with the Mollusca, which develop from a larval form comparable with that of some worms.

The class BRYOZOA, or POLYZOA, Moss-corals or Sea-mats, resemble the Hydrocorallines in appearance, being polyps with tentacles arranged round a circum-oral disc called the **lophophore**, and usually disposed in colonies; but in reality they are very different. They are distinguished from them by possessing an excretory opening (anus) and a body-cavity.¹ They reproduce themselves asexually as well as sexually—the asexual germs, found in the fresh-water species, being called **statoblasts**. The cuticle of each polyp hardens into a cell, called the **ectocyst**: the coral-like mass is built up by the adhering walls of successive polyp-cells. The individuals bud while yet in the larval stage.

¹ There are cases in which it is stated to be indistinguishable.

Some of the marine forms are polymorphic, that is to say, some of the polyps are modified to subserve special uses to the colony. These polyps are degenerate forms : they are called vibracula and avicularia ; the former bear a long flagellum, hence their name ; the latter are modified into a bird's-head shape very much like that of the pedicellariæ of the sea-urchins. The Polyzoa are very numerous represented on our coasts, coating stones or seaweed, or growing free, as in the case of the most common form, *Flustra*, the



Fig. 81.—Shell of *Terebratula*, showing beak of the shell perforated by a foramen for the passage of the peduncle.

Sea-mat. There are also several fresh-water forms. They all form interesting objects of microscopic study.

The Lamp-shells, class BRACHIOPODA (arm-footed animals), used to be classed with the Mollusca. They have an inequivalve bivalve shell, the two halves of which are placed dorsal and ventral to the animal, and are attached either directly by the shell or by a ligament called the **peduncle**, which sometimes perforates the beak, and sometimes passes out between the valves. The feature of the group is the pair of

“arms,” which are usually coiled round in a spiral, and sometimes supported by a spiral skeleton, consisting of loops derived from the dorsal valve of the shell to which they are fixed. They bear ciliated tentacles, and have been compared with the tufts of the worm *Sabella*; they are partly respiratory, and partly used for sending food particles to the mouth. There are numerous fossil forms, the class having attained its maximum in past periods.



Fig. 82.—One of the surviving species of **Lamp-shell** (*Terebratula Maxillata*); shell seen in profile.

There are some forms in which the so-called arms are not fixed, but are capable of being extended to some distance. In this case the supporting structures are short.

CHAPTER IX.

TUNICATA OR UROCHORDATA.

Animals more or less resembling in structure the Sea Squirt.

Classes.—LARVACEA, with persistent urochord.

THALIACEA, or Free-swimming Ascidians.

ASCIDIACEA, or Sea-squirts.

THE TUNICATA, Ascidians, or Sea-squirts, as has been already stated, are sometimes classified with the Vertebrates in a group called Chordata, and sometimes as a separate group. The group receives its names (coated animals, leather-bottle animals) from the fact that the creatures have a tough cuticle or skin, which is composed of a material called **Tunicin**, similar in composition to vegetable cellulose. The mouth opens into a cavity perforated with small respiratory holes (gill-holes); this cavity also leads to the intestine, and therefore unites the respiratory with a share in the alimentary function. Hence it has been called the **Pharynx**, because that is the name given to the enlarged part of a fish's throat which bears the gills, and to the cavity at the back of the mouth in man and other animals, which both leads to the gullet, and receives the openings from the nostrils (*posterior nares*), and therefore unites alimentary and respiratory functions. Surrounding the pharynx is an outer

chamber, called the atrial chamber (*atrium* = entrance hall), which may be continued far down into the stalk of the animal.

Not far from the mouth is another opening, called the **atrial pore**, or exhalent pore (cloacal opening),

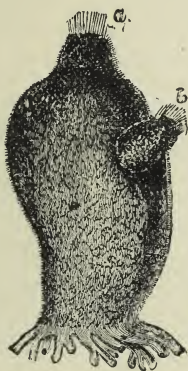


Fig. 83.—Simple Ascidian, one of the Sea-squirts (half natural size): *a*, incurrent aperture; *b*, excurrent aperture.

which expires the water that has served for respiration, carrying also with it the excretory products which are expelled into the atrial chamber by the

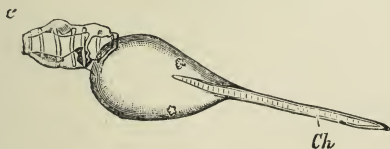


Fig. 84.—Larval Ascidian, showing urochord, *i.e.*, homologue of the vertebrate notochord. *Doliolum* larva, one of the Thaliaceæ, with larval tail; *ch*, chorda (urochord).

anus, and the generative products which are also sent into it by their efferent ducts. The heart undergoes regular contractions, but they sometimes reverse their direction, thus reversing the blood-stream, a very curious fact. The animals may be either fixed or floating, single or colonial. They sometimes present

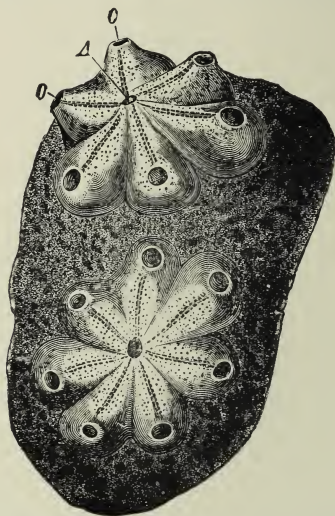


Fig. 85.—Compound Ascidian (*Botryllus*), one of the Ascidiaceæ. *O*, mouth of one individual. *A*, excurent aperture common to the group of individuals.

an alternation of generations. The Ascidians are a group in which the larval form differs considerably from the adult. The larva in some cases possesses eyes which are lost in the adult. The tail, furnished with a **urochord**, which is usually atrophied in the adult, has been already named (p. 77).

The Ascidians are quite common animals of the sea-shore, many of them being found fixed to stones or shells near low-tide mark. If touched, when they have been left dry by the tide, they squirt the contents of the atrial chamber through the mouth and exhalent pore, whence they get the name of Sea Squirt. One of the commonest, often found on oyster-shells, is bright red. Some of the colonial forms are very pretty, the animals being grouped in stars or patterns; they may often be found on the fronds of tangle, etc. The colonial forms *Pyrosoma* and *Salpa* are highly phosphorescent.

Those Tunicates in which the adult retains a tail and a notochord are sometimes placed in a class by themselves, under the name of PERENNICHORDATA, or of LARVACEA, because they resemble the larval forms of the rest of the group. The remainder are sometimes included under the general name of CADUCICHORDATA, or Tunicates which lose their notochords, and may be divided into two classes, the THALIACEA and the ASCIDIACEA. The former are free forms, and have the exhalent aperture placed at the opposite end of the body from the inhalent aperture, while among the fixed forms belonging to the latter the two apertures are near together (fig. 83).

ENTEROPNEUSTA OR HEMICHORDATA.

Balanoglossus, already named as a worm-like marine animal, which is a link between vertebrates and invertebrates, may be placed here for the sake of con-

venience. It received the group name of ENTEROPNEUSTA before that of Hemichordata was bestowed upon it on account of its possessing a notochord. The larva resembles that of an Echinoderm. The animal receives its generic name, acorn-tongued, from the shape of its contractile proboscis, which serves as

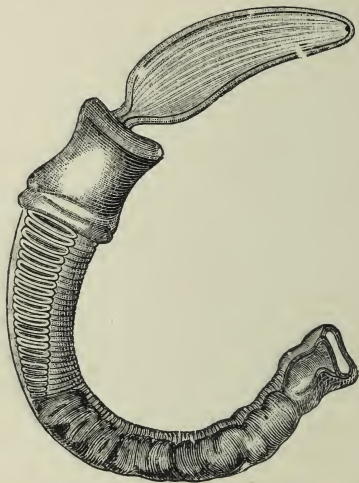


Fig 86.—*Balanoglossus*, a link between vertebrates and invertebrates, showing proboscis and lateral gill-slits.

a locomotive organ. The notochord arises in connection with the pharynx (throat). There is a dorsal nervous cord. In respiration, the water goes in at the mouth and out at the gill-slits, which in structure resemble those of Ascidians, consisting of numerous small holes. In the young animal, however, there is only a single pair of gill-slits.

CHAPTER X.

VERTEBRATA.

Animals more or less resembling the Frog in structure (see p. 304).

Classes.—FISHES. AMPHIBIA. REPTILES. BIRDS. MAMMALS.

THE Vertebrata, or animals with backbones, form a group very sharply defined from the rest of the animal kingdom, and yet there are, as has been stated, several interesting links between them and the lower groups.

Link between Vertebrates and Invertebrates.—Two of these links, *Balanoglossus* and the Ascidian, have already been referred to; a third, *Amphioxus*, is included, in classification, among the Vertebrates themselves, although it can only be looked upon as a sort of *poor relation* of the true Vertebrates. It is so different from the true Vertebrates, that it has to be put into a sub-division by itself. All other Vertebrata have true heads, clearly distinguished from the region of the spinal column, and a backbone; but *Amphioxus* has nothing worth calling a head, and it has no backbone, though it has the essential structure which in other vertebrates precedes the backbone in development, namely, the notochord. To meet this difficulty, the name of CHORDATA (animals with a noto-

chord) is used as a name for a group including both *Amphioxus* and the Vertebrates, while the *Amphioxus* itself receives as a group name that of *Cephalochordata*. This name expresses the fact that it has no true head; for it refers to the position of the notochord, which goes on right to the front of the body, whereas in vertebrate embryos the notochord stops at the middle region of the brain. Many other group names have been given to this little animal, namely those of *Acrania* (skull-less); *Pharyngobranchii* (pharynx-gilled); *Cirrostromi* (fringe-mouthed, because it has filaments round its mouth); and *Leptocardii* (slender-hearted, because its heart is represented merely by a contractile blood-vessel). It is only by courtesy that all these names are put in the plural, since *Amphioxus* is the sole genus of its type. Few animals have had so many names given them all expressing some special peculiarity. Its generic and specific names are also descriptive of its peculiarities: *Amphioxus*, sharp at both ends (Greek ἀμφί and ὀξύς, sharp), and *lanceolatus*, lance-shaped, i.e., tapering at both ends, both referring to its headless structure.

At first sight *Amphioxus* might be described as a very worm-like little fish; but there are some respects in which its structure is really wonderfully like that of an Ascidian. It is, however, practically bilateral in symmetry, though not quite so. Its breathing arrangements are, in the adult state, precisely those of the Ascidian. The water, respired, entering through

the mouth, is squeezed through the gill-slits into a cavity, corresponding with the atrial cavity of the Ascidian, which opens to the outside by an atrial pore. In the typical Ascidians, the atrial pore is also the excretory opening; but in the *Amphioxus* there is an anus as well, situated a little more towards the tail. Structures which appear to be rudimentary fins, in the form of long, but boneless, ridges suggest that *Amphioxus* resembles the true fishes; so does also the disposition of its muscles, which form, as in fishes, regular successive masses. These successive masses of muscles have been considered to be signs that the Vertebrates are descended from animals that were metameric like the worm or lobster.

In other respects, however, the structure of *Amphioxus* is very low; not only has it no true head, but its eye is only represented by an unpaired pigment spot, its nose is represented by a pit lined with ciliated cells, and it has no ears at all. Instead of a definite heart, it has pulsating blood-vessels.

The young *Amphioxus* differs from the adult sufficiently to be spoken of as a larval form. It commences its existence as a ciliated gastrula.

The true Vertebrates.—The complexity of the organs of the Vertebrates is so great that any systematic description of them would be impossible in a small book like this. We can therefore only just touch on a few of the salient points of the chief groups, leaving the reader to consult the larger textbooks referred to (pp. 323–4) for further information.

The Skeleton.—Of the characters common to all the classes of the Vertebrates, the most obvious at first sight is that to which they owe the name Vertebrata, *i.e.*, the possession of a jointed backbone to protect the central nervous cord. The existence of this central dorsal nervous cord, and the special development of its front end into a **brain**, similarly protected by a **skull**, is the real distinctive feature of the Vertebrates. The existence of internal bones forming an **endoskeleton**, to support or protect the various important structures, is, however, in contrast with the usual structure of the Invertebrata, which have their hard protective structures developed on the outside of the body, forming what is called an **exoskeleton**. Whether this contrast is as striking as it seems at first sight is as yet uncertain. There are, however, a few bones in the Vertebrate skeleton, which belong to the outside of the body and have travelled inward (see p. 261).

The skeleton of Vertebrates consists of the following chief parts:—the **axial skeleton**, already named, *i.e.*, spinal column and skull, protecting the central nervous system; the ribs, supporting the muscular walls of the trunk, some of which are connected in front in nearly all Vertebrates but fishes with a breast-bone or sternum; the bones of the forelimbs and hind-limbs, with the bones by which they are attached to the trunk, called respectively the **pectoral girdle** (Lat. *pector*; breast) and the **pelvic girdle**. The parts of the pectoral girdle on each side

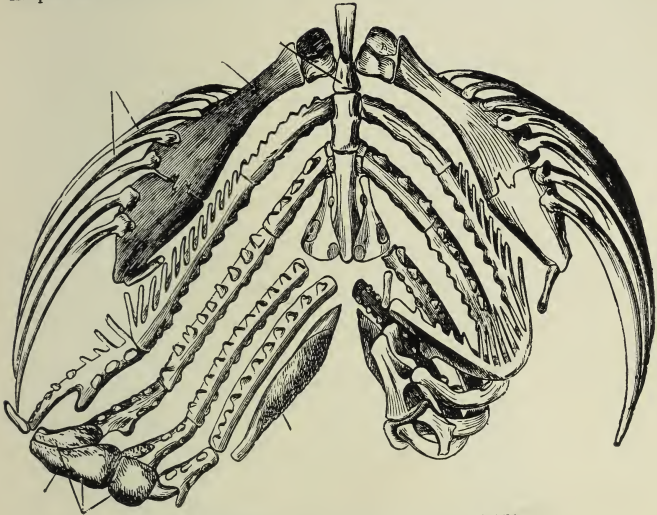
are, in mammals, the **scapula**, or shoulder-blade (dorsal), and the **clavicle**, or collar-bone (ventral), while in the *Prototheria*, or lowest mammals, and in most other Vertebrates, there is also another ventral piece, called the **coracoid**, and in amphibia and reptiles some additional parts are respectively distinguished. The pelvic girdle consists of three bones on each side, the **ilium** (dorsal) and the **ischium** and **pubis** (ventral); these form the **pelvis** (Lat. *pelvis*, a basin), so called from its shape in the human skeleton. These parts are only found in animals higher in the vertebrate scale than fishes; but it has been shown that they are in a measure comparable with the bony pieces at the base of fishes' fins. The ordinary vertebrate limb is regarded as derived from a fin type, the bones of the digits being restricted in number and increased in size. Thus our hands and feet, with five tolerably similar digits, are less a departure from the primitive type than the wing of the bird, which retains only three digits, or the foot of the horse, which retains practically only one. Besides these must be named the **branchial skeleton** (*i.e.* skeleton of the gills, Gk. *βράγχια*, gill), which, though very small in the reduced state in which it exists in the higher Vertebrata as the **hyoid** bone (see p. 245), is yet very important, on account of the light that its development throws upon the relationship of the various groups of Vertebrates.

The Vertebrates have various features which mark them as metameric or segmented animals, *e.g.*, the

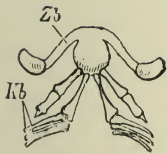
existence of successive pairs of gills (or in the higher vertebrates of structures which are their homologues), and of two successive pairs of limbs; while the successive pairs of nerves given off from brain and spinal cord, the successive joints of the backbone itself, and the successive pairs of ribs associated with some of them, are among other traces of metameric structure, like the muscle-masses already named. These, although, in all Vertebrates higher than fishes, their original character is more or less lost, are seen in the embryo of higher forms: for instance, in an early stage of the developing chick, successive pairs of masses of tissue are seen, from which the muscles of the body are afterwards developed. These muscle-plates are sometimes called **somites**, because they are believed to be comparable with the successive body-rings of a segmented animal. Some think, however, that the metamerism of the vertebrate body, instead of being an indication of ancestral structure, may have arisen independently from the working of the tendency to the repetition of parts consequent on the elongated form of the body.

The Cranial Nerves. The skull is believed to consist of a number of successive parts which are probably to be regarded as metameric, nobody knows how many, all fused together. Some trace of these fused segments is seen in the successive pairs of nerves given off by the brain; but some of these, too, are probably formed by the union of several pairs into one. The brain gives off twelve pairs of nerves, of which the first

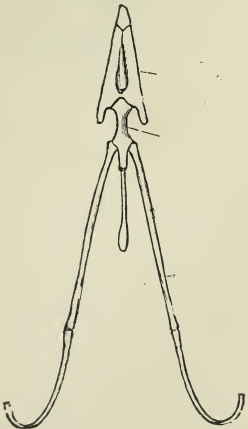
Fig. 87.—The Branchial Skeleton of a fish, and its representative in an Amphibian and in a Bird.



Branchial Skeleton of the Perch, *Percia fluviatilis*.



Hyoid bone of a Urodele Amphibian, *Menopoma*: *Zb*, hyoid part; *Kb*, remains of the branchial arches. (From Claus and Sedgwick.)



Hyoid bone of the Hooded Crow, *Corvus cornix*. (From Claus and Sedgwick.)

pair go to the nose, and provide for the sense of smell ; the second go to the eyes, and provide for the sense of sight ; while the eighth go to the ears, and provide for the sense of hearing. The tenth nerve is called the

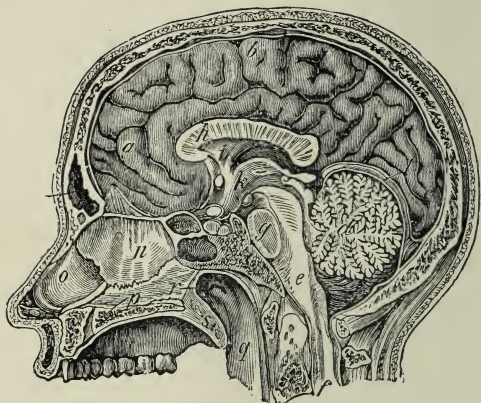


Fig. 88.—The most complicated form of vertebrate brain, that of Man, seen in section.

vagus, or *wandering* nerve, because its branches spread all over the body, governing the digestive organs, heart, and lungs : on account of its distribution, it is also called the *Pneumogastric* (lung and stomach nerve). In a fish's head these pairs of nerves may be seen lying in order ; but in the heads of the higher vertebrates, owing to the folding and overlapping of the parts of the brain, the order in which the cranial nerves succeed one another is more difficult to make

out. In the compact skulls of the higher vertebrates, however, their places are approximately marked by their *foramina*, *i.e.* the holes (*Lat. foramen*, a hole) through which they pass in the skull; and hence they may conveniently be studied at leisure in the dry skull.

Classes of the Vertebrata. The Vertebrata are divided into five classes, the FISHES, AMPHIBIA, REPTILES, BIRDS or AVES, and MAMMALIA.

The FISHES are exclusively aquatic; they therefore have gills to breathe with, and retain them all their lives.

The AMPHIBIA are the only vertebrates that have a larval stage different from the adult. This larval stage is fish-like, being provided with gills; the Amphibia and Fishes are therefore sometimes classed together under the name of *Ichthyopsida* (fish-like animals). The adult stage, tho' popularly called a "reptile," differs from one in having two **occipital condyles**, *i.e.* joints, by which the skull is set on to the top of the spinal column.

The name SAUROPSIDA is sometimes used to include under one heading the REPTILES and the BIRDS, animals so different in appearance that, when the name was given by Professor Huxley, no one had previously thought of classing them together. They agree, however, in the important particular of having the skull set on by *one* condyle only; and there are fossil types which form links between the two, and thus show that they are related.

The MAMMALIA agree with the Amphibia in having two condyles, and differ from all the other vertebrates in having no nucleus in the red corpuscles of the blood. The chief distinction, however, between them and all other animals, is that from which they derive their name, namely, that they suckle their young, which are produced alive instead of being hatched from eggs.

Fishes. It will be easily understood from what has been said in Part I., Chap. IV., that since the Amphibians (which in their adult stage are comparatively highly-developed animals) have a larval stage that is like a fish, we therefore suppose that all Vertebrates are descended from fish-like ancestors. This is rendered still more certain by the fact that the higher Vertebrates, though they have not, like Amphibians, a free fish-like larva, yet pass through a fish-like stage in the development of the embryo. As already mentioned (p. 56), the developing chick exhibits at an early stage the *rudiments of gills*; and the same is true of other groups at a corresponding stage.

The gills of fishes consist, in their most primitive form, of holes passing from the throat and opening to the exterior, each lined with tissue adapted for respiratory purposes, and supplied with fine capillaries in which the blood gets filled with oxygen. The holes are spoken of as the gill-clefts. A large looped blood-vessel carries the blood to and from each; these vessels are spoken of as the vascular arches of the gills.

The development of the gills varies very much in different groups of fishes; in some the gill slits open directly to the exterior; but in the bony fishes (*Teleostei*) there is a common intermediate cavity, covered by a structure called the **operculum**, or gill-cover.

The modification of the various pairs of gills is believed to have given rise to very different structures. One of these is the **Eustachian tube**, which in Mammalia passes from the throat to the ear, and is believed to represent one of the gill-clefts. The bones which support the gills are composed of paired arches of bone, supported by a median rod; part of this branchial skeleton persists in the higher Vertebrates as the **hyoid** (U-shaped) bone, which supports the tongue, while another part is represented by one of the small bones which exist inside the ear. In some fishes there are four gill-bearing clefts, and in some as many as seven.

In addition to the above modifications, it is also supposed by some anatomists, that the limbs of Vertebrates are derived from pairs of gills, the movable filaments of which became changed into fins, and travelled down the body of the fish. Others suppose that the ancestors of the Vertebrates had a fin ridge all along the side of the body, just as some fishes have a fin ridge all along the middle of the body, and that this became restricted in position, and enlarged in size, forming a fin. This belief is chiefly founded on the nature of the fins of *Amphioxus*,

which has two lateral fin ridges exactly like its median one, only that they do not extend all the way to the tail.

The differences between fishes and the other Vertebrates may be summarized by saying that they retain a primitive elongated form and metameric symmetry which reminds us of articulated animals, while the higher Vertebrates have many of their parts doubled and folded upon one another, so as quite to obliterate their original arrangement. For instance, the brain of fishes consists of parts placed one behind another in a row; but in mammalia, and most of all in the human subject, these parts are doubled over one another in a kind of zigzag—an arrangement which results from the fact that in the mammal the cerebral hemispheres are much more developed than the other parts, and have to make room for themselves by overlapping them.

FISHES.

Classification of Fishes.—Fishes are divided into the orders described below. Excluding the *Amphioxus*, which has already been spoken of, the *Cyclostomi* or *Marsipobranchii*, comprising the Hag-fishes and Lampreys, are the lowest order of fishes. They have round suctorial mouths, as is indicated by their first name, and they have six or seven pairs of pocket-like gills. They live in mud, and hold on by their suctorial mouths to stones, or to whatever they

are feeding upon. The Hag-fishes are parasitic upon living fish, and the Lampreys eat chiefly dead fish or other carrion. It will be remembered that Roman epicures are said to have fed their lampreys now and then upon a drowned slave. The *Cyclostomi*, unlike other fishes, have no scales. They have the beginnings of what constitutes the skeleton in other animals. The notochord persists, instead of being replaced by the backbone, as in higher types; and it is supplemented by bars of gristle (cartilage), which represent the beginnings of joints of the backbone. There is a brain, and a cartilage skull surrounding it, which has no bones except in the basal part; and the mouth is armed with teeth. Although in outward appearance these fishes are rather wormlike, it will be seen that they represent an immense advance on *Amphioxus* in having a brain, teeth, and the beginnings of a skeleton. They have, moreover, two eyes and a distinct heart, so that altogether they resemble *Amphioxus* only in the persistence of the notochord, a peculiarity that they share with other groups of fishes presently to be described. Their whole structure, and especially that of the head, is so greatly modified in accordance with their suctorial habits, that it is difficult to draw from the study of these animals any conclusions as to the way in which they have been developed from lower forms; but it is a suggestive fact that one of the Lampreys has a larval form, with no eyes and no teeth, which acquires both as it grows older. This larval form was at first

described under the name of *Ammocætes*; it is an

interesting exception to the general rule that Vertebrates, excepting Amphibia, do not have larval forms.

The Sharks, Skates, and Dog-fishes, or *Selachii* (*Elasmobranchs*), are also called *Chondropterygii*, or gristle-finned; the skeleton is for the most part made up of cartilages instead of bones. They have, like most other Vertebrates, four limbs, two pectoral fins and two pelvic fins; and, in addition to these, they have median fins. In some important respects, these fishes are very highly organized; they have

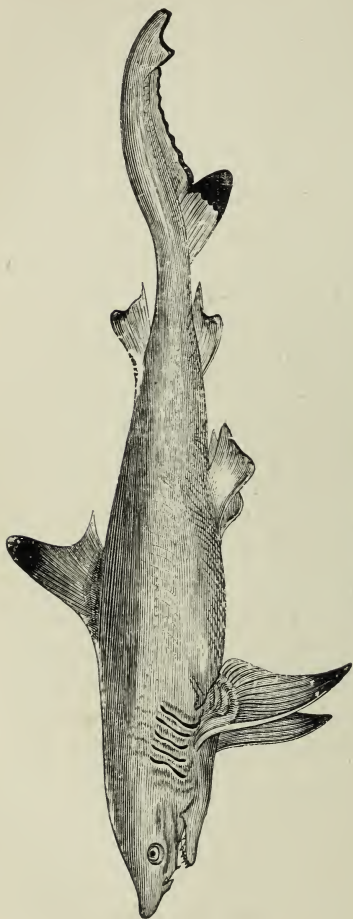


Fig. 89.—A Shark, *Carcharias melanopterus*.

better-developed brains than any other fishes. Dog-fishes are common, and may easily be obtained for study. The cartilaginous skull is often found on the sea-shore at certain seasons—an oblong object which is very puzzling at first sight. The egg-shells also are often seen: those of the dog-fish are transparent

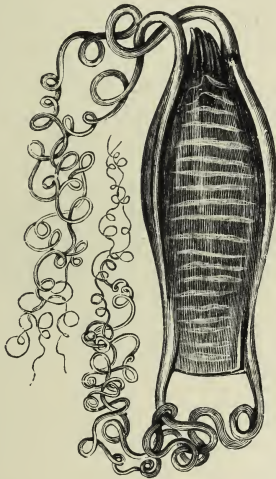


Fig. 90.—Egg of a Dog-fish, *Scyllium*.

and greenish, with four long tendril-like strings, by which they attach themselves to seaweeds: those of the skate have four short horns instead, and have a black shiny surface which is suggestive of a beetle. The skin of the Dog-fish is rough with small bony granules, which are ossifications of the projections or papillæ of the dermal layer of the skin. These were

formerly called placoid scales, and they are comparable with the primitive form of *teeth*; for there are small teeth in some of the *Selachii* that exist as similar ossifications in the mucous membrane of the mouth, and the latter is only a continuation of the outer skin. That all teeth have originated from this simple form is proved from the way in which teeth arise in the embryo animal, namely, as papillæ (fig. 92), which afterwards become hardened by deposits of hard material. Larger teeth are also found in many Selachians, which are believed to have been derived from the fusion

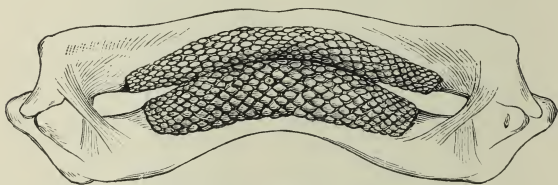


Fig. 91.—Jaws of Skate, showing multiple rows of teeth.

of the smaller kind, and to be comparable with the teeth of higher types (fig. 91). In sharks there are a number of these teeth arranged in rows one inside the other, so that the front row is most used in biting. Such a fish has a practically unlimited number of sets of teeth, the back rows coming into use when the front ones wear down. In the two successive sets of teeth possessed by mammals (milk teeth and second teeth) it is believed that we see a reduced representation of these successive rows, the number being reduced to two, and these so modified by their

more complicated development in sockets, that their succession in time is more readily apparent than their succession in place. Some fishes of this group have also larger scales, sometimes armed with a protective bony spine. These larger scales are also regarded, like the larger teeth, as having been developed by means of the fusion of the smaller ones. It will be

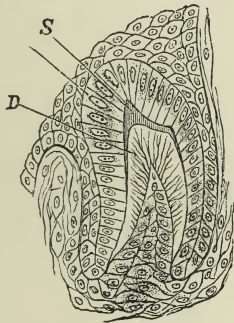


Fig. 92.—Development of the embryonic tooth of a Newt. *D*, Dentine of the tooth, formed in a papilla of the cutis. *S*, Enamel of the tooth. (From Claus and Sedgwick, after O. Hertwig.)

seen further on, that those important little placoid scales are not only regarded as having built up large teeth and large scales, but also as having had, in the course of the development of vertebrates, a little share in the building up of bones. Although the name placoid scale is still retained in books, it is a very misleading one, because very few of these scales are flat; they are often little bony knobs of very irre-

gular shape, and sometimes armed with a projecting spine.

The *Ganoidei*, fishes which are not so numerous now as in former ages, receive their name from the polished armour of scales with which many kinds are invested. These scales are covered with a layer of polished enamel, derived from the epidermis; they are fitted into one another, but scarcely overlap. The best known living member of the order is the Sturgeon: it has a cartilaginous skeleton and a persistent notochord. But the cartilaginous skull is supplemented by what are called dermal bones, and in many other ganoid fishes there are a number of well-developed bones. The group is therefore in a manner intermediate between the Dog-fishes and the Bony Fishes, although, as regards its armour of scales, it is unlike either. The scales themselves, with their polished enamel, may be compared to teeth placed outside; but although they have been distinguished by a special name, owing to their coat of enamel, it must be remembered that they are not greatly different from the so-called placoid scales, which also are covered by an element derived from the epidermis, though it is not so noticeable.

The Bony Fishes, or *Teleostei*, constitute the great majority of fish, including all the familiar kinds, such as the herring, eel, pike, salmon, cod, mackerel, etc. Their skeleton is bony, not cartilaginous. The notochord persists as a soft tissue placed centrally between the joints of the backbone. Each joint of bone presents a hollow on both sides, where a soft pad of

notochord is placed ; and the vertebræ of fishes are therefore said to be biconcave or amphiœlous. The scales of the *Teleostei* are sometimes round at the edges (cycloid), and sometimes fringed at the edges (ctenoid or comb-like). The order is divided into a great number of sub-orders, tribes, and families. The *Pleuronectidæ*, or Flat-fishes, which include the Sole (fig. 94), Flounder, and Plaice, deserve a word of notice because they are among the commonest fishes

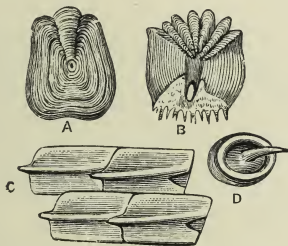


Fig. 93.—Scales of Fish: A, Cycloid; B, Ctenoid; C, Ganoid; D, Placoid.

of our coast, and are at the same time very exceptional in their structure. They have become curiously adapted to their habit of lying on the sandy bottom of the sea, their bodies being both twisted and flattened, apparently by constantly lying on one side, so that the arrangement of the head and bones is crooked with regard to the original median plane of the body, and adapted to the new median plane developed by the flattening process. The result is, that both eyes are placed on one side of the head. Flattened animals, as has already been

remarked, are usually animals that live on sand, the flat shape being well adapted to prevent their sinking in when at rest. Some Flat-fishes have another peculiarity that fits them for their mode of life; namely, they have the power of changing colour. Although the lower side, turned away from the light, is white, the upper side is full of pigment cells; and according as these change their shape, thus concentrating or distributing the colour they contain, the

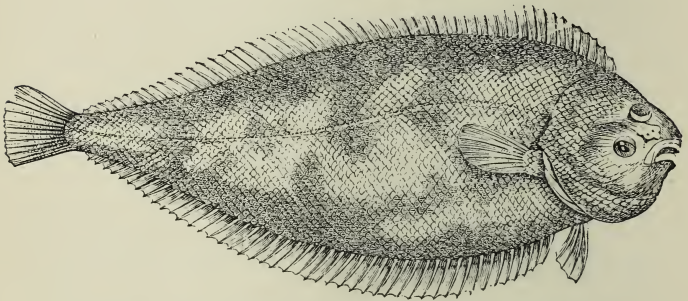


Fig. 94.—One of the Flat-fishes, the Common Sole (*Solea Vulgaris*).

animal becomes lighter or darker. Whether the activity of the nerves which govern these pigment cells is always a case of reflex action, or whether they are ever controlled by the will of the fish, is uncertain; but the fish changes colour according to the colour of the patch of ground it is resting on, becoming dark on a dark patch and light on a light patch, an arrangement which must be an admirable protection against being detected either by animals that want to

eat the fish or animals that the fish wants to eat. Hugh Miller, the self-taught geologist, observed this change of colour in the Flounder, without having seen the fact recorded in any book : a circumstance which should afford a useful hint to self-taught naturalists. A similar arrangement in the Cuttle-fish has already been referred to. Something of the same kind happens in the Frog, which changes colour to a certain extent ; and the most remarkable instance of change of colour occurs in the reptile called the Chamæleon. The colour changes of the latter were perhaps exaggerated in the descriptions which were at first given by travellers, but they are, nevertheless, of a remarkable character. It is interesting to observe these cases of a similar kind occurring in animals differing so widely from each other as the cuttle-fish, flounder, frog, and reptile ; in each of them the purpose is the same, to enable the animal to escape detection by approximating to the colour of its surroundings. These instances show how similar circumstances of life may impart a superficial similarity regarding *one* characteristic to animals of widely differing origin. It is probable that in all these animals changes of colour are excited by anger or fear ; and it is interesting to compare the way in which human beings show different feelings by blushing or turning pale : in this case the nerves act on the blood-vessels instead of acting on pigment cells of the skin, as in the other cases.

The order of fishes called *Mud-fishes*, or *Dipnoi*,

form a link between Ganoid Fish and Amphibia, being the lowest kind of vertebrates that have lungs. One, the Barramunda or *Ceratodus*, is found in Australia, one, the *Protopterus*, in Africa, and one, the *Lepidosiren*, in Brazil. While they resemble fishes in having gills and a persistent notochord supplemented by bony arches, four fins, and a compressed tail, they resemble Amphibians in having lungs. These lungs are of a very simple character, and arise just in the same way as does the swimming-bladder of ordinary fish, namely, as a sac, paired or unpaired, which is filled with air, and opens by a duct into the pharynx. Hence we see that the lungs of vertebrates, although the *analogue* of the fish's gills, are the *homologue* of its swimming-bladder; that is to say, they fulfil the same use as the former, but have the same origin in development as the latter.

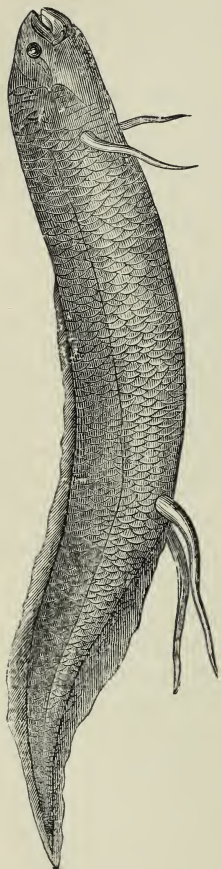


Fig. 95. — A link between fish and amphibia, the Brazilian Mud-fish, *Lepidosiren paradoxus*. The gills are internal.

Cartilage Bones, and Membrane Bones.—It has been seen that, as we pass upwards in the series of fishes, we usually find the cartilage of the skeleton more and more replaced by bone. In the higher vertebrates it is practically entirely so replaced in the adult, cartilage remaining only in places where it is useful as a soft pad. The cartilage becomes directly transformed into bone, undergoing certain histological changes, and the deposition of a quantity of mineral matter. Bones so formed are called **cartilage bones**. But there are bones of another kind, called **membrane bones**, because the tissue which exists before ossification sets in is of a fibrous character, or **dermal bones**, because they are derived from the dermis. From the manner in which these bones are seen to be formed in the embryo, and from the comparison of different types, it appears that they are really *scales* (placoid scales, see p. 255) belonging to the deeper layer of the skin, which have sunk in, till in the course of development they have joined on to the cartilage bones, and come to form part of the skeleton. Thus, in the case of the Sturgeon, we find a skull of cartilage, with bones of this kind lying outside it. In the skull of a Teleostean fish the cartilage of the skull is replaced in the adult by cartilage bones; and the membrane bones, instead of merely lying outside them, are fastened to them. They are, however, not fastened very firmly; for in these fishes the different bones of the skull are irregular in form, and very loosely joined, instead of being firmly united into a

rounded skull, as in the higher vertebrates. In the frog's skull, too, it may be clearly distinguished that the membrane bones are applied outside the cartilage bones; but in the higher vertebrates this is not so, and the membrane bones can only be distinguished from the others by tracing their existence throughout the vertebrate series.

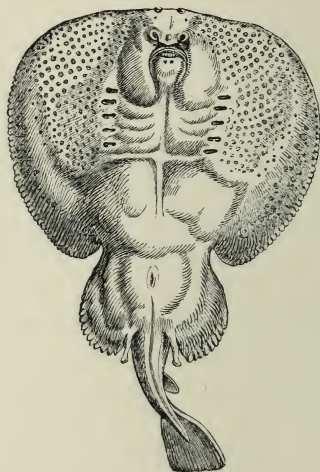


Fig. 96.—The Electric Ray (*Torpedo*), under side. The spotted areas indicate the place of the electric organs.

Electric Fishes.—One of the most curious and important facts to be recorded in connection with Fishes is the existence, in some fishes, of electric organs. These fishes belong to different groups, the *Torpedo*, or Electric Ray, being one of the Selachii, while the *Gymnotus*, or Electric Eel of South America,

is one of the *Teleostei*; and the organs of the former are developed in the head, while those of the latter are near the tail. Other electric fishes have also been described. The organs of the *Torpedo* consist of a number of similar columns, transversely divided into similar compartments; each of these contains a layer of very moist tissue, and a flat structure called the "electrical plate," richly supplied with nerve-endings somewhat comparable to the characteristic nerve-endings which motor nerves form in muscular tissue. The nerve-endings are distributed to the same side of the plate throughout the organ, and the surface on which they are found is electro-negative, while the other is electro-positive; but how the energy of the nerves gives rise to electric energy is not yet understood.

AMPHIBIA.

Links between Fishes and Amphibia.—We see, in the familiar form of the Tadpole, the most striking instance of a link between fishes and amphibia. In the spring the student should get some Tadpoles and study their successive stages. Some adult amphibians retain certain fish-like characters. The *Cacilie*, for instance, snake-like animals found in Brazil, have fish-like biconcave vertebræ with persistent remains of the notochord. Those amphibians which never lose their gills have also biconcave vertebræ. The extinct animals called *Labyrinthodon* (from the complicated pattern of folds in their teeth)

had these fish-like vertebræ, and also an external armour; and they have been considered to afford a link between Amphibians and Ganoid Fishes. The *Dipnoi* also are, as already stated, links between Fishes and Amphibia.

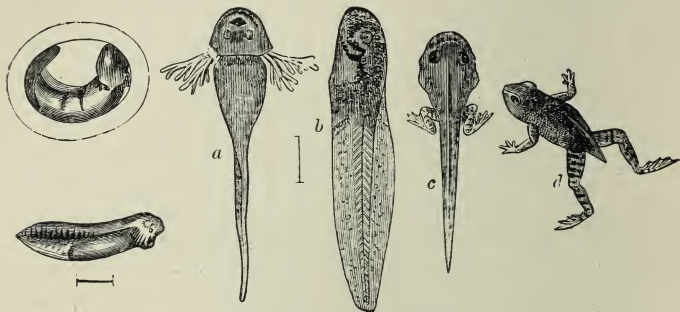


Fig. 97.—Successive stages of the development of the Frog, from the Fish-stage to the Amphibian.

Characters of Amphibia. The possession of a larval stage is the most marked peculiarity of Amphibians among vertebrata. The adult stage, being chiefly adapted for terrestrial life, has limbs with finger-like digits, and lungs adapted for breathing air. Amphibia are distinguished from Reptiles by having two occipital condyles, whereas Reptiles have only one. Amphibians have a characteristic kind of skin. It is almost invariably without scales, but provided with glands, which secrete a fluid that keeps the skin moist, and is sometimes of an acrid character; in which case it doubtless acts as a protection against enemies.

Classification of Amphibia. — The *Cæcilæ*, snake-like animals, already referred to as possessing fish-like vertebræ, form the group *Gymnophiona*. They are not, however, as the name would imply, destitute of scales, but have very small ones arranged in transverse rings. In the young stage some of them have gills; and they are therefore classed with Amphibia. They live under the soil. They have no limbs, and have accordingly received the group name of *Apoda* (without feet). The rest of the Amphibia are

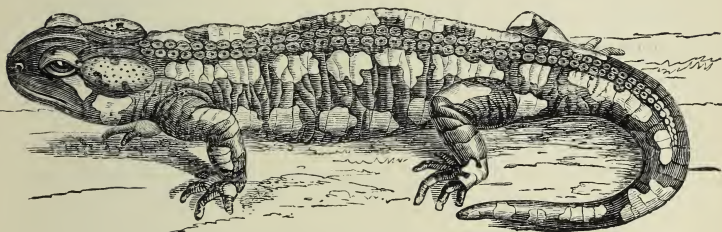


Fig. 98.—A Salamander (*Salamandra maculata*).

classified according to their tails. The higher forms, Toads and Frogs, or *Batrachia*, are called *Anura*, because they have no tail in the adult form. The rest of the group, including among others the Newts and Salamanders, and the Axolotl, are called the *Urodela*, or *Caudata*. The Newts (*Triton*) are the English representatives of the Urodela. The Salamander is a European form of larger size; it is viviparous. The Axolotl is a Mexican animal which sometimes loses its gills when it is adult, and sometimes does not, accord-

ing to the conditions under which it is placed. The higher forms of the Urodela, instead of having fish-like biconcave vertebræ like the lower forms, have vertebræ which are opisthocœlous, *i.e.* hollow on the posterior surface only. The Anura, on the contrary, have vertebræ which are procœlous, *i.e.* hollow in front only. All these varieties of vertebræ are also represented among the reptiles.

REPTILES.

Links with other Classes.—The question of the relationship of Reptiles with the lower vertebrates would be a very difficult matter to discuss; but the existence of extinct reptiles with fish-like biconcave vertebræ affords at least one link (fig. 99). There is more to be said about the relationship of reptiles with higher groups; and, as will be stated under the head of these classes, we have very distinct evidence of the relationship of reptiles with birds, and also of the relationship of reptiles with mammalia.

Characters of Reptiles.—The Reptiles never have a larval stage like that of Amphibia, but are always air-breathing animals. They are slow in movement, and are cold-blooded. The bones of the pectoral girdle may be again named here, for their arrangement in reptiles presents a type from which may be derived the arrangements of them seen in the remaining classes of the vertebrates, Birds and Mammals. The pectoral girdle consists on each side of a dorsal part, the shoulder-bone, or *scapula*, articulating

with a ventral piece, the *coracoid*; the latter articulates ventrally with the median breast-bone or sternum, and is overlaid by a membrane-bone called the *clavicle* or collar-bone. Between the clavicle lies an additional median bone, the *interclavicle*; this is especially characteristic of reptiles, and is not often seen elsewhere. Other subordinate elements are sometimes distinguished. The pelvic girdle consists correspondingly of three pieces on each side, dorsally the **ilium**, which is connected with the spine, and ventrally the **ischium** and **pubis**. The fore-limbs are respectively attached at the joint between the scapula and the coracoid, and the joint between the ilium and ischium. While the higher reptiles have usually five digits, it may be noticed that in some extinct reptiles a more fin-like type of limb was present.

The Reptiles, although they resemble the lower groups of the vertebrate series in being cold-blooded, differ from them in possessing a structure called the amnion, which enwraps the embryo in the egg. They share this character in common with Birds and Mammals, and the three classes are therefore sometimes grouped under the name of **Amniota**, while the Fishes and Amphibia (Ichthyopsida) are referred to under the name of **Anamniota**. The same is true of another embryonic structure called the Allantois, and the group names **Allantoidea** and **Anallantoidea** are therefore similarly employed.

The distinguishing external feature of Reptiles is the great development of the armature of the skin, consisting of scales or of bony dermal plates. The

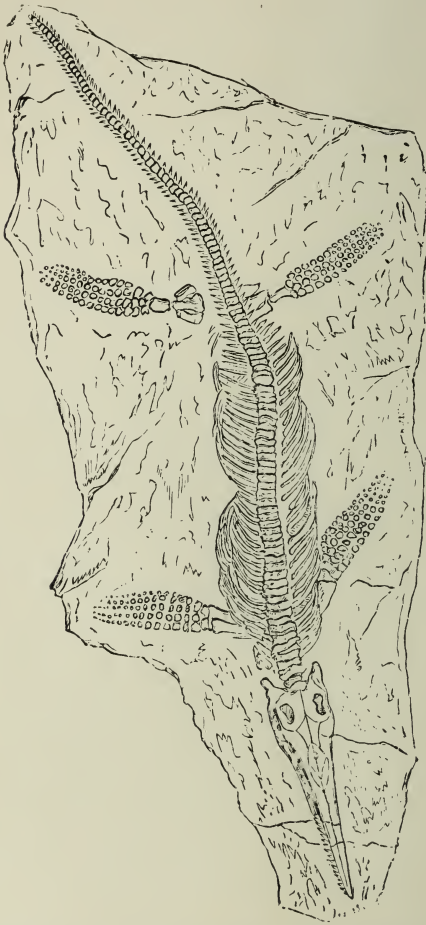


Fig. 99.—*Ichthyosaurus*: An extinct Saurian, with fish-like vertebræ, and fin-like limbs.

most obvious features that distinguish Reptiles from Amphibia are the want of a larval stage and the possession of one occipital condyle instead of two.

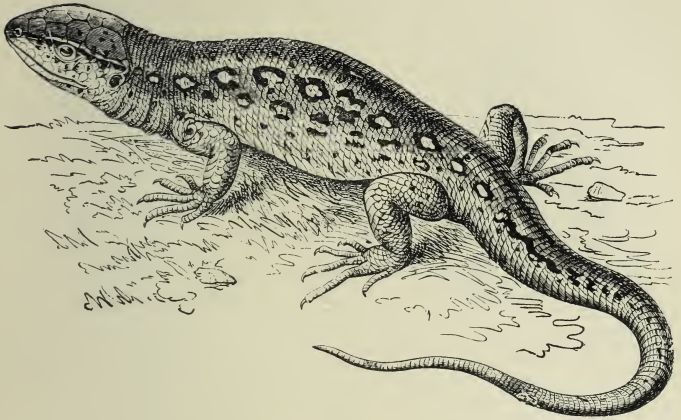
Classification of Reptiles.—The Reptiles fall into three great groups, the Snakes, or *Ophidia*, characterized by the reduction of the limbs, and the adaptation of the body to movement by crawling; the *Saurii*, or Lizards, which usually have four limbs; and the *Chelonia*, or Turtles, which have the body invested by a continuous armour of bony plates.

The *Ophidia* live on animal food of various kinds, including insects, frogs, birds, and mice. They are covered with an armour of scales, the colours of which, dark brown and green for the most part, are such as to render them inconspicuous, and thus help them to steal unperceived on their prey. Their jaw-bones are so constructed as to allow the mouth to open very wide, and they can therefore swallow prey of comparatively large size. The teeth of snakes are hooked and conical. In addition to ordinary teeth, the poison snakes have also poison teeth, which are grooved or perforated by a canal, through which the poison from the poison duct runs down when the snake bites. These teeth are in the upper jaw. Snakes have no trace whatever of the fore-limb or pectoral girdle, but some of them have rudiments of the hind limb. They have a great number of ribs, which play an important part in helping them to crawl. Most snakes lay eggs, but a few are viviparous. The Viper, *Pelias berus*, is the only venomous snake found in England; it is

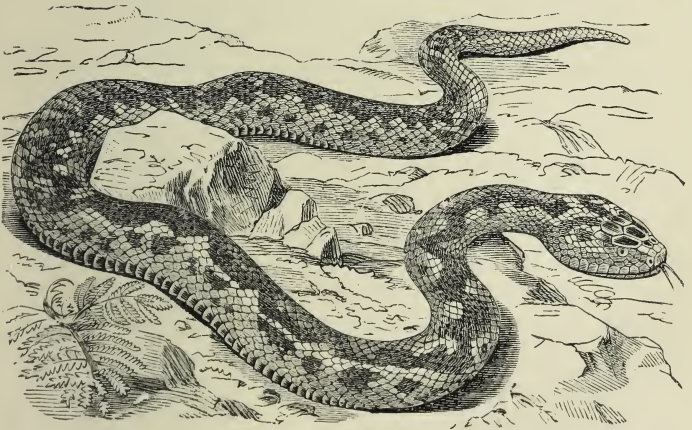
not often met with. The common English Snake, called the Grass Snake, *Tropidonotus* (or *Coluber*) *Natrix*, is quite harmless; it is sometimes called the Ringed Snake, from its collared appearance, due to the presence of a pair of pale spots, followed by a contrasting dark area at the back of the head.

The *Saurii* include the Chameleons, Iguanas, and Lizards, and the Crocodiles, besides a number of extinct forms. Some of the latter resemble fishes in having amphicoelous, that is to say, biconcave, vertebræ. The Crocodiles have vertebræ that are concave in front (procoelous), while some extinct kinds had vertebræ concave behind (opisthocœlous). The living Crocodiles include the true Crocodile of the Nile, the Alligators of America, and the Gavials, or Indian crocodiles.

A few of the Lizards resemble snakes in outward appearance; among these is the English Slow-worm, or Blind-worm (*Anguis fragilis*), which sometimes is a cause of fright to those who dislike snakes, but is quite harmless. The little Lizards which may be found on sunny banks are the only other English representatives of the *Saurii*; we have two kinds, the Scaly Lizard, *Zootoca vivipara*; and the Sand Lizard, *Lacerta agilis*; and a third, *L. viridis*, is found in Jersey.



A



B

Fig. 100.—Two English reptiles: A, the Sand Lizard, *Lacerta agilis*; B, the Viper, *Pelias berus*.

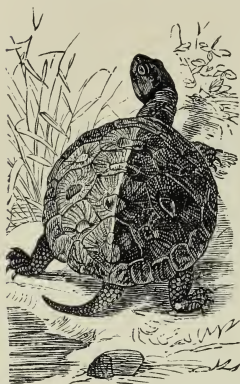


Fig. 101.—The common Tortoise,
Emys lutaria (or *europæa*).

The *Chelonia* include the Turtles, and several groups of Tortoises. They have no teeth, but a beak somewhat resembling that of a bird. The limbs are usually more or less adapted for swimming as well as for walking. The head and limbs can usually be retracted under the shell. The back of this shell is called the carapace, and the front is called the plastron.

BIRDS (AVES).

Links between Birds and Reptiles.—Strange as it seems at first sight, the slow and cold-blooded reptile is closely related to the birds, the most active and consequently the most warm-blooded of the Vertebrates. This is shown, not only by the similarity of their structure in many respects, but by the existence of links between the two. One of these links is afforded by the *Odontornithes*, fossil birds which have teeth, instead of possessing a toothless beak, like other birds. Another link is afforded by a fossil bird called *Archæopteryx*, which possessed teeth, and had moreover a long tail with separate vertebræ, and corresponding successive pairs of feathers, instead of a modified tail with fused vertebræ and crowded

feathers, such as exists in other birds. The extinct reptile called *Pterodactyl* may also be regarded as a link between the two groups, for it had the power of flight. Its wing was not constructed like that of a bird, but appears to have been in some respects like that of a bat, existing as an expansion connected with the digits or fingers, one of which was enormously

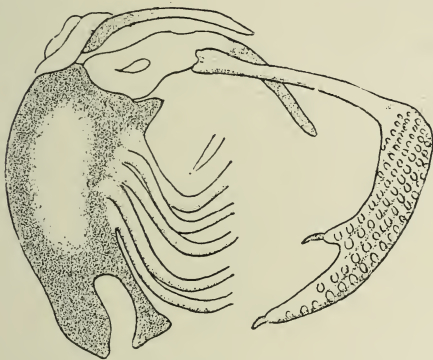


Fig. 102.—Breast-bone and shoulder-girdle of an embryo ostrich of 27 days' incubation, showing reptilian type of coracoid and claws on the wing. (From *Proc. Zool. Soc.*, June, 1885.)

large; whence the name *Pterodactyl*, or wing-fingered animal.

Reptilian features may be traced, too, in some birds. The coracoid bone of the ostrich, *e.g.*, consists in the unhatched bird of a wide perforated plate, similar in type to the coracoid of some reptiles, and is but slightly modified in the adult. The ostrich, and one or two other birds also, have claws on the digits of the wing;

these are of little use, and must be interpreted as ancestral structures.

The structural resemblances between birds and reptiles have led to their being classed together, as before stated, under the name of SAUROPSIDA.

Characters of Birds.—Birds agree with reptiles in having nucleated blood corpuscles, and one occipital condyle, in laying eggs, and in the course of development which the embryo in the egg undergoes. But otherwise they differ from them greatly: reptiles are cold-blooded animals, and usually slow-moving; birds are the most active of vertebrates, and their temperature is accordingly higher than that of other vertebrates. The modification of the fore-limb to form the wing, and the presence of a covering of feathers, many of them specially adapted to assist in flight, are the most obvious distinguishing characters of birds. The structure of the bones, which are filled with air cavities in order to make them light, is another adaptation for aërial life. The beak is a distinctive structure present throughout the class.

Classification of Birds.—Birds are divided into two great groups, the *Ratitæ*, or birds with flat (raft-like) breasts, and the *Carinatæ*, or keel-breasted birds. The former group, which is a very small one, includes the African ostrich, the Australian ostrich, or emu, the cassowary, and the American ostrich (*Rhea*); and the Kiwi, or *Apteryx* (wingless bird) of New Zealand. All these have the wings more or less reduced in size, and run instead of flying. The latter group includes

the rest of the birds, and is divided into sub-groups according to characters which are dependent on the respective modes of life adopted by birds. These are as follows:—The *Natatores*, or Swimming Birds, include

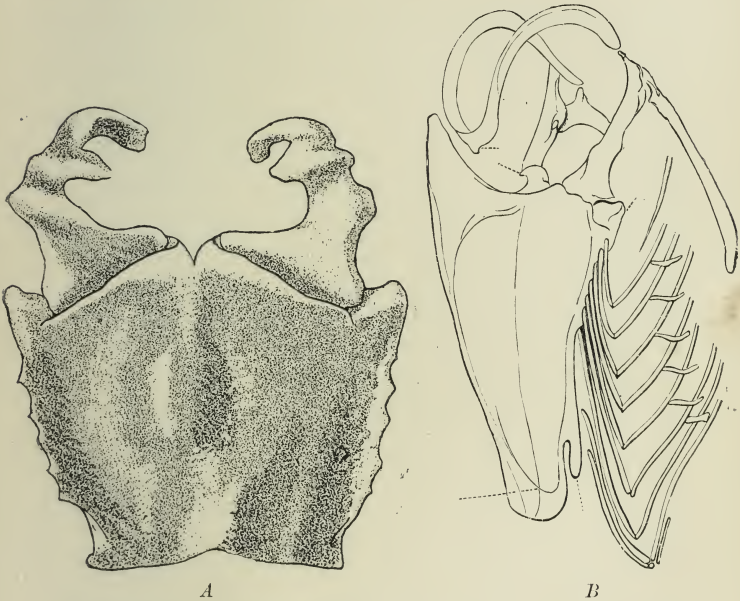


Fig. 103.—A, Breast-bone of a Ratite bird, the Ostrich, showing absence of keel. B, Breast-bone of a Carinate bird, the Guillemot, showing presence of keel. (From *Proc. Zool. Soc.*, June, 1885.)

the gulls, gannets, divers, ducks and geese, and swans, and also the penguins, which differ from these in being swimming birds *only*, and incapable of flight. The typical *Grallatores*, or Waders, have long legs adapted

for wading in swamps, and long necks adapted for stooping down and searching in the mud for their food; they include the plovers, snipes, storks, herons, ibises, and cranes, and also the water-hens, corn-crakes, and bustards, which are connecting links between this group and the *Rasores*. The *Rasores*, also called Gallinaceous or Poultry Birds, can run better than they can fly, and get their living and their name by scratching up the soil to find seeds and insects: they include the fowls, pheasants, turkeys, grouse, and partridges. The *Columbinæ*, or Pigeons, are nearly related to them, but live among trees or rocks instead of on the ground. The *Scansores*, or Climbing Birds, have their feet adapted for climbing trees: the group contains birds of very different types, though alike in this respect; it includes the parrots, toucans, woodpeckers, and cuckoos. The *Insessores*, or birds that perch, are also called the Passerine Birds, because the sparrow (*Passer*) is a typical form. They are divided into tribes, according to the form of the beak. The *Levirostræ*, birds with light beaks, but of large size, include the kingfishers, bee-eaters, and rollers, and the hornbills of Sumatra. The *Tenuirostræ*, or birds with narrow beaks, include the hoopoes, the honey-suckers, and the humming-birds, the smallest of all birds (fig. 104). The *Fissirostræ*, or birds with cleft beaks,—goat-suckers, swallows, swifts, and martins,—are so called because the opening of the beak is very deeply cut; the beak can therefore be opened very wide, which enables the

birds to find their food by catching insects on the wing. The *Dentirostres*, so called because the upper beak has a slight notch near the point, include the crows, rooks, starlings, shrikes, and flycatchers, and the titmice, and wagtails, wrens, and thrushes. The *Conirostres*, with a strong, short, cone-like beak, include the larks, finches, and weaver birds. The last order of the *Carinatae* are the *Raptores*, or birds of prey. These are distinguished by their especially strong beaks and claws, and they have a soft membrane or cere, covering the root of the beak ; they include owls, vultures, eagles, and falcons, and the secretary bird of Africa, which lives on snakes. The other birds of the order usually live on birds and mammals.

Various classifications have been framed to supersede the above. Professor Huxley has classified birds according to the characters of certain bones in the skull, and there are other and newer classifications.

The Intelligence of Birds.—In some respects birds may almost be said to dispute with mammals the right to be regarded as the most highly developed of the Vertebrates. The high perfection of their locomotive powers, the intelligence manifested in the building of their nests, and the varied range of feelings evinced by their powers of varied song, all entitle them to a high place in the scale of animal life. The well-contrived homes which so many of them build are only the outward expression of the existence of the family affections : the care of the parent bird for its young has afforded a symbol of the most unselfish and

devoted love for the poets of all ages, from the Hebrew Psalmist to the writers of the present day; while the attachment of a bird to its mate is such that if one dies, the other often pines away and does not long survive. This is believed to be invariably the case with the love-bird, a kind of parrot which has received its name for that reason.

Many birds have not only a family life, but also a social life. The weaver birds that build a social nest,



Fig. 104.—Nest of the Humming Bird, one half the natural size.

and the migratory birds that fly in flocks, are instances of this. Not among the least interesting examples of social birds are our own English rooks; their habits have often been observed, but we are still far from understanding all their little ways, which yet offer to the naturalist a wide field of study. The acquisi-

tive habits of the magpie and others of its tribe, which steal and hoard up all sorts of objects that strike their fancy, especially those that glitter, compare curiously with the ways of uncivilized man. As for the intelligence of the parrot, starling, and other birds that learn to imitate human language, and to use it for their own purposes,—for they usually bring their vocabulary into play when they are hungry,—it may be favourably contrasted with that of their captors, who rarely learn to use more than one note of bird language.

The behaviour of birds towards man would seem to be to some extent a matter of heredity. Every one knows how easily a robin may be tamed, and how soon it will learn to fly into the house and to eat out of one's hand. There is at least as much reason to believe that this general tendency to friendliness with the human species is the hereditary result of the respect the bird has long enjoyed, in consequence of the pretty legends that exist about it in many countries, as that the legends are due, on the contrary, to the natural boldness of the bird, as is sometimes suggested. It is probable that an equally kind treatment would in a few generations make most birds equally tame; and when human beings learn to study the intelligence of birds in a rational manner, winning them to friendliness instead of shooting them or shutting them up in cages, we shall doubtless learn a great many valuable facts which are now hidden from us. Every one may do something to contribute towards this very desirable result: for wherever food and water are regularly set for birds, and they are encouraged to remain by protecting the nests and offering suitable nest-building material in the right season, there birds will multiply, and allow to friendly eyes many interesting glimpses of their ways; while often, in bad weather, rare birds will be found to come to the place where food is set, as well as the familiar visitors.

MAMMALIA.

Link between Mammalia and Reptiles.—

The Mammalia, or animals that suckle their young, are connected with Reptiles by the existence of a link between them, the Australian animal called the duck-billed mole, or *Ornithorhynchus* (bird-billed animal).

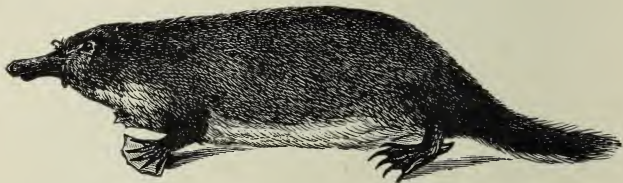


Fig. 105.—The Duck-billed Mole, *Ornithorhynchus paradoxus*, a link between Reptiles and Mammalia.

To this animal, with another similar kind, called *Echidna*, the group name of MONOTREMATA has been given. The structure of its pectoral girdle is like that of a reptile, and, like a reptile, it lays eggs.

Characters of the Mammalia.—The Mammalia, as already stated, are the only vertebrates which have non-nucleated red blood corpuscles. The blood is warm. Another general character is that they have teeth which are placed in sockets, and usually developed in two series, the first, or milk teeth, falling out when the others push them out by their growth. Besides teeth developed in sockets, another universal characteristic is the presence of **hair** on the skin, which is never entirely absent, and in the vast majority

of kinds forms a complete covering. The hairs arise each from a root placed in a pit or follicle situated over an eminence or papilla of the skin.

Classification of Mammalia.—The MARSUPIALIA are, after the MONOTREMES, the least highly developed



Fig. 106.—*Didelphys dorsigera*, an Opossum from Surinam, carrying its young on its back.

of the Mammalia. They are the *archaic type* of mammals, and now survive chiefly in the Australian region. Their especial peculiarity is, that they have a pouch or *marsupium*, in which they carry their young about, to keep them warm and shelter them from danger. Some

of the Opossums, some tree-climbing marsupials, in which the pouch is not so well developed as that of others of the group, carry their young about in a singular manner: the tail is prehensile, and the young curl their tails round that of the mother, and thus ride about securely on her back. Other marsupial mothers sometimes carry the young about on their backs, but do not possess so convenient a way of making them safe.

The marsupial animals are of very different kinds, having become modified with a view to their food habits, so that they mimic other groups of animals. Thus there are marsupial Carnivora, which resemble the true Carnivora in the shape of their teeth and skull; and marsupial rats, which are very like the true rodents in appearance, and marsupial herbivora and insectivora. (See figs. 111, 114, 121.) The *Marsupialia* used to be looked upon merely as one of the *orders* of the Mammalia; but they are now understood to differ so widely from the higher Mammalia, that they are sometimes made into a group called METATHERIA, divided into sub-groups according to the differences of structure just spoken of, while the orders of the higher Mammalia are classed under another group called EUTHERIA. The Monotremes are then distinguished as PROTOTHERIA. This classification is largely based on the structure of the reproductive organs: the names ORNITHODELPHIA, DIDELPHIA, and MONODELPHIA, are also used as equivalents of the names just given, to indicate respectively the Mono-

tremes, Marsupials, and higher Mammals. The young of the Metatheria are born in a very early stage of development, and are subsequently further developed in the marsupium; while the young of the Eutheria are born in a much more advanced stage, and are attached before birth to a special structure called the placenta. They are therefore called Placental Mammals.

The orders classified under the name Eutheria include the Sloths, or *Edentata*, Whales, or *Cetacea*, the order including Horses, called Odd-toed Ungulates, or *Perissodactyla*, the order including Sheep, called *Artiodactyla* or Even-toed animals, the Elephants or *Proboscidea*, the Rats or *Rodentia*, the Hedgehog family, or *Insectivora*, the Seals or *Pinnipedia*, the Cats and Dogs, or *Carnivora*, the Bats, or *Cheiroptera*, the Lemurs, or *Prosimiæ* (ape-like animals), and the Monkeys, or *Primates*, under which, zoologically speaking, is included Man.

Each of these orders is a group distinctly defined in habits, and in structure corresponding to those habits. Hence the distinction which was made the basis of early classifications was that of their habits regarding food. Now a classification based on this stands good up to a certain point, for similar food habits necessitate some similarity in the structure of the teeth, paws, etc.; but, as we have just stated, such a similarity may arise secondarily in animals which differ greatly from one another in other respects, and thus we have *Carnivora* in the widely-differing groups of

the *Metatheria* and *Eutheria* (Marsupials and higher Mammals), the Marsupial Carnivora being called *Rapacia*, and the others *Carnivora*. The orders of the Mammalia are therefore founded on many other characters besides those relating to food habits and dentition.

Teeth of Mammals.—The differences in teeth, which exist in correspondence with differences in habits, although not fundamental characters, are the readiest means of distinguishing between mammals of different groups, and they vary so much, that they are also the readiest means of distinguishing between different genera.

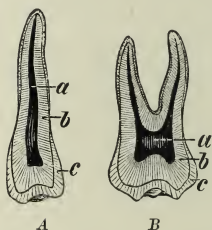


Fig. 107.—Human teeth seen in section, showing the different materials of which they are composed. A, Pre-molar; B, Molar; b, dentine; c, enamel; a is the pulp-cavity of the tooth.

The teeth of Mammals consist of three substances: the **enamel**, which is the thin hard outer coat of the tooth; the **dentine**, which lies beneath it and forms the major portion of the tooth; and the **cement**, a tougher substance closely allied to bone, which in human teeth occupies a restricted position,

merely clothing the roots of the tooth, but in the molars of ruminants may cover the sides of the tooth, and, until it has been worn off by use, the crown also. The part of a tooth which lies above the gum is called the crown, the part below the gum is the root or fang; the centre is occupied by the **pulp cavity**, which affords passage for the nerves and blood-vessels.

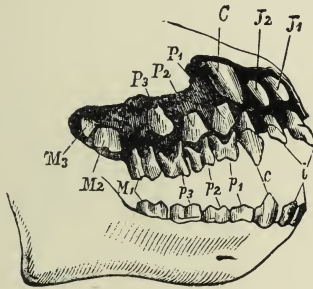


Fig. 103.—Succession of teeth in mammalia. Jaws of an Ape (*Cebus*) while changing its teeth, showing permanent teeth (marked with capitals), under the milk teeth (marked with small letters). (From Claus and Sedgwick, after Owen.)

Some kinds of Mammalia never have but one set of teeth: these are called *monophyodont*, *i.e.* producing one set of teeth only. It is a rare arrangement, found among the sloths and in some of the whales. Most mammalia are *diphyodont*, that is to say, they produce two sets of teeth, the first, or milk teeth, giving way to a second set, as the animal attains its adult age. This second set are usually more numerous, the increase taking place, of course, at the outside of the

set, *i.e.* towards the articular part of the jaw-bone. The teeth of mammals are divided into **incisors** or front teeth, **canines**, **premolars**, and **molars**, *i.e.* cheek teeth or “grinders”; but all these are not always present together.

The incisors, which occupy the most central region of the jaw (premaxillary bone in the upper jaw, and the opposite part of the lower one), are, as a rule, distinguished from the canines, which lie next, by their

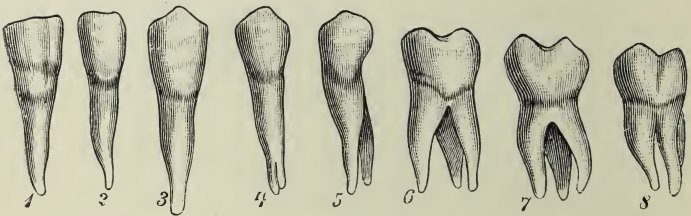


Fig. 109.—Teeth of Man. Dental formula, $\frac{2\ 1\ 2}{2\ 1\ 2} \mid \frac{3}{3}$.

1=1st incisor.
2=2nd incisor.
3=canine.

4=1st premolar.
5=2nd premolar.
6=1st molar.

7=2nd molar.
8=3rd molar or wisdom tooth.

shape; premolars are, as a rule, distinguished from molars by the fact that the former have predecessors among the milk teeth, while the latter only appear in the second set. All these may be looked upon as modifications of a common type, much as in vegetable morphology foliage leaves, bracts, sepals, petals, stamens, and carpels, are all looked upon as modifications of a common leaf type—or as the walking legs, claws, antennæ, and jaws of a lobster are looked upon

as modifications of a common type of "appendage." For the sake of brevity, a series of figures called a **dental formula** is used to indicate the number of different kinds of teeth possessed by an animal. The upper row of figures in the formula refers to the upper jaw, the lower row to the lower jaw. Thus the teeth of man are 32 in number; there are present on either side in each jaw two incisors, one canine, two premolars, and three molars: this may be written, i. $\frac{2-2}{2-2}$, c. $\frac{1-1}{1-1}$, pm. $\frac{2-2}{2-2}$, m. $\frac{3-3}{3-3}$ = 32; or, more shortly, by writing the half only and omitting the total, i. $\frac{2}{2}$, c. $\frac{1}{1}$, pm. $\frac{2}{2}$, m. $\frac{3}{3}$; while if it is written more shortly still, $\frac{2\ 1\ 2\ 3}{2\ 1\ 2\ 3}$, an upright stroke may be added between the figure which represents the premolars and that which represents the molars, thus: $\frac{2\ 1\ 2}{2\ 1\ 2} \left| \frac{3}{3} \right.$. The milk teeth of man would similarly be represented by the formula, i. $\frac{2-2}{2-2}$, c. $\frac{1-1}{1-1}$, d. m. $\frac{2-2}{2-2}$ = 20, d. m. standing for deciduous molars. In referring to one kind of tooth only, the full formula must be used, to prevent mistakes: thus the incisors of man are $\frac{2-2}{2-2}$, that is to say two for each side in each jaw; while the canines are $\frac{1-1}{1-1}$, and so on. The incisors are the

biting teeth, and have their best development in the rodents; the canines are the *fighting* teeth, and have their best development in the Carnivora and other animals that are combative; *e.g.* pigs, gorillas, and some deer; the molars are the *chewing* teeth, and have a different development according to the kind of food the animal eats. Thus, in the Primates, which are frugivorous, the prominences on the top surface or crown of the tooth, called cusps, are rounded, so

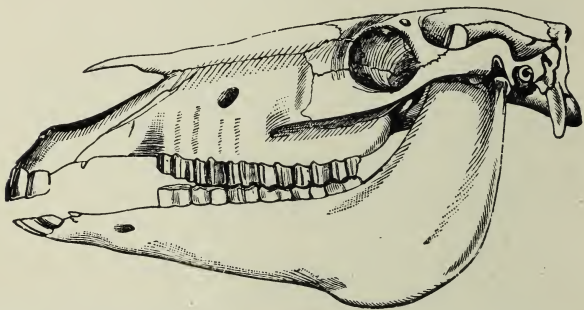


Fig. 110.—Herbivorous dentition of Horse, *Equus caballus*. Dental formula, $\frac{3 \ 1 \ 4}{3 \ 1 \ 4} \left| \begin{smallmatrix} 3 \\ 3 \end{smallmatrix} \right.$; but one of the premolars is soon shed; canines rudimentary in female.

as to be suited for chewing foods which require to be crushed (cf. fig. 109, 6, 7, 8). The molars of herbivorous and carnivorous animals respectively present characteristic features, which distinguish them from molars of the frugivorous type, as well as from each other.

Herbivorous Dentition. In the typical Herbivora, the tops of the molar teeth are divided into sharp ridges, so as to chop the grass and herbage that

they chiefly live on; these ridges are formed by an alternating arrangement of the substances which compose the crown of a tooth, the polished outside substance, enamel, the dentine, and the cement. The canines are frequently absent, and whether they are absent or not, there is a wide gap between the incisors and premolars. The Marsupial herbivora resemble the true herbivora in the presence of this gap, as well as in the possession of ridged molars (figs. 110, 111, 117). Many ruminants, sheep and cows for example, have no incisors in the upper jaw.

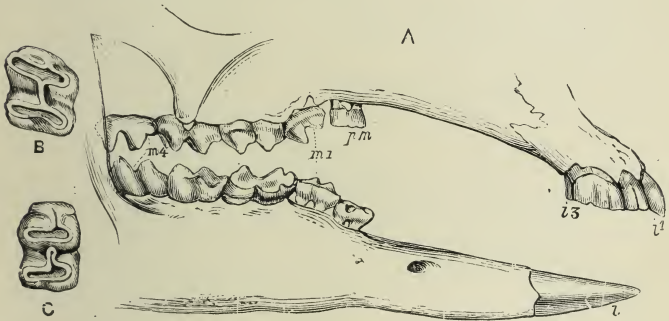


Fig. 111.—Herbivorous dentition of a Marsupial, the Great Kangaroo, *Macropus giganteus*. A, upper and lower jaws; B, upper, and C, lower molars, with ridged crown. Dental formula, $\frac{3 \ 0 \ 1}{1 \ 0 \ 1} \bigg| \frac{4}{4}$.

Carnivorous Dentition.—In the Carnivora, however, the molar teeth being formed to tear the tough material of animal flesh, the cusps are very sharp, and those of opposite teeth interlock, instead of opposing one another. There is usually one molar

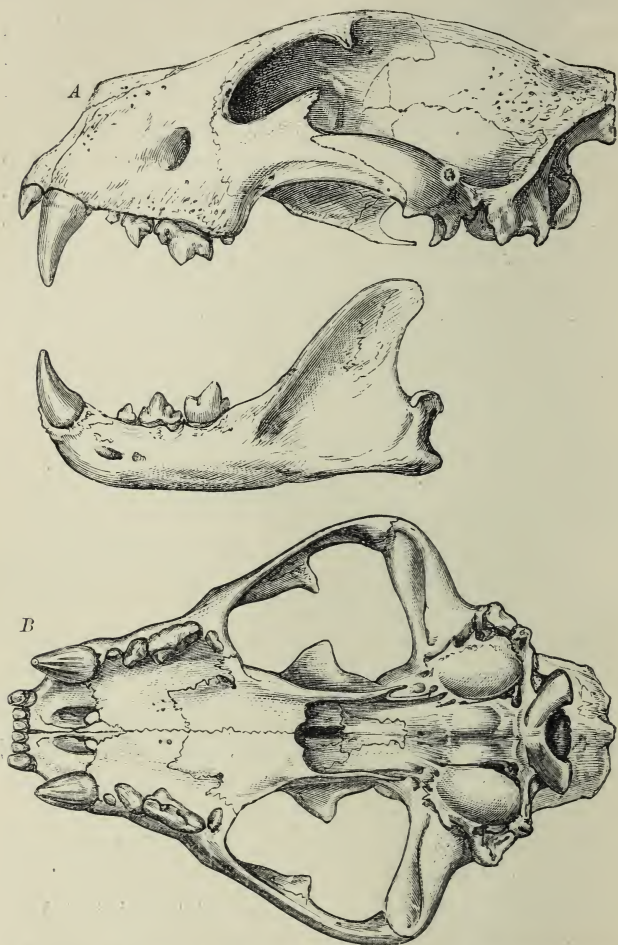


Fig. 112.—A, Carnivorous dentition; skull of Lion, *Felis leo*; side view, one-fourth natural size. B, Same viewed from below. Dental formula, $\begin{array}{c} 3 \ 1 \ 3 \\ 3 \ 1 \ 2 \end{array} \left| \begin{array}{c} 1 \\ 1 \end{array} \right.$

tooth rather larger and sharper than the rest : Cuvier called this the **carnassial** (flesh-eating) tooth ; it is one of the chief typical features of the dentition of the Carnivora. The outer part of the crown rises up into a sharp blade divided into narrow triangular

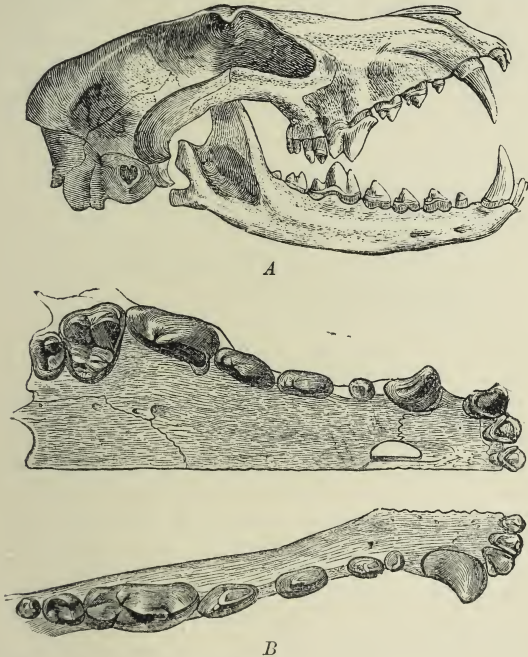


Fig. 113.—A, Carnivorous dentition ; skull of Wolf ; *Canis lupus*. B, Teeth of Dog. C, *familiaris* (upper and lower jaws). Dental formula, $\frac{3 \ 1 \ 4}{3 \ 1 \ 4} \begin{array}{c} 2 \\ 3 \end{array}$

cusps, while the inner part is low, forming a low tubercle ; in some animals even this is, in the lower jaw, further reduced (cat). The tooth which becomes

modified into the carnassial tooth is, in the lower jaw, always the first molar, and in the upper jaw, the last pre-molar. In the Bear group of the Carnivora, which are not so exclusively carnivorous as the cats or dogs, this tooth is not so decidedly developed. In the Marsupial Carnivora there are usually several teeth of this pattern, but not one specially large one that can be distinguished as *the* carnassial tooth. The general

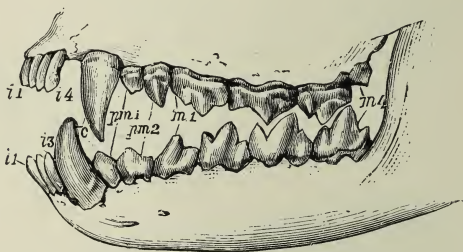


Fig. 114.—Carnivorous dentition of a Marsupial. Dental formula, $\begin{array}{c|c} 4 & 1 & 2 & 4 \\ \hline 3 & 1 & 2 & 4 \end{array}$.

characters of carnivorous dentition are thus given in Tomes' "Manual of Dental Anatomy" (2nd ed., p. 376):—"In a general sense we may say that the characters which indicate a pure flesh diet are: the small size of the incisors as compared with the canines, and their arrangement in a straight line across the jaw; the large size, deep implantation, and wide separation from one another of the canines; the reduction in the number of the molar series, those that remain being without broad crushing surfaces, in the place of which a pointed or sharp-edged form prevails.

Thus the more numerous the teeth of the molar series, and the broader their crowns, the more likely is it that the creature subsists on a mixed diet; and a gradation may be traced even in individual teeth, such as the carnassials, in which a gradual increase in relative size of the internal tubercular cusps of the upper, and of the posterior tubercles of the lower teeth, may be traced as we pass from the examination of the teeth of the *Felidæ* (cats) to those of mixed feeders, such as the *Arctoidea*” (bears).

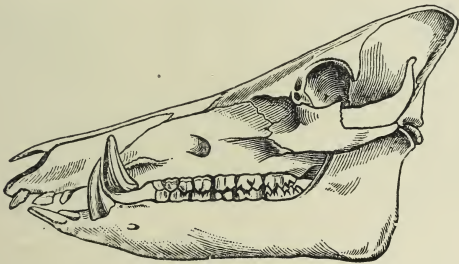


Fig. 115.—Skull of Wild Boar, *Sus scrofa fera*, showing tusk-like canines. (From Claus and Sedgwick.)

The Canine Tooth.—The canine tooth, popularly supposed to be a characteristic of carnivorous dentition, is such only in so far as it is the tooth that enables an animal to seize its prey: it is the fighting tooth, and may exist in animals that are purely herbivorous. It was shown by Cuvier, and long previously by Aristotle, that although the canine is absent in many nearly related animals, yet it is present and very long in

some deer which have no horns, or only small horns ; in these it is the only fighting weapon. A good

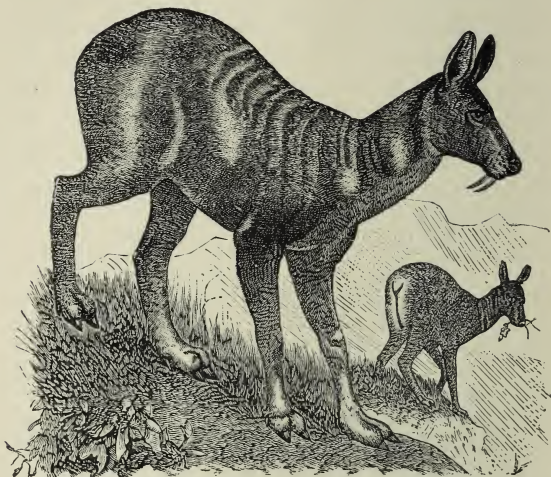


Fig. 116.—The Musk Deer, *Moschus moschiferus*.

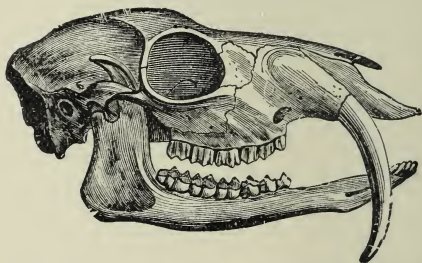


Fig. 117.—Skull of the Male Musk Deer, *Moschus moschiferus*, showing tusk-like canines existing in a herbivorous animal.

instance of this is the musk deer, *Moschus mos-*

chiferus, in which the male has the canines developed into long tusks, while the female has only very small canines : this is the case also with several other kinds of deer. The Camel and the Dromedary have canines, and use them for aggressive purposes, and the tusks of the Boar are shown in fig. 115. The tusks of the Walrus are the canines, developed so as to enable the animal to tear up seaweed from the rocks, and to climb on land ; they are necessary to the animal's mode of life, and are only incidentally used for fighting, as may be judged from their development in the female as well as the male. The caniniform tooth is not always the same tooth of the series ; the one which is usually the first premolar is caniniform in the lower jaw of *Oreodon*, an extinct herbivor. Nor is a *tusk* always a canine : the tusks of the elephant are incisors.

Insectivorous Dentition.—The molars of insect-eating animals are distinguished from those of the

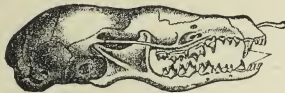
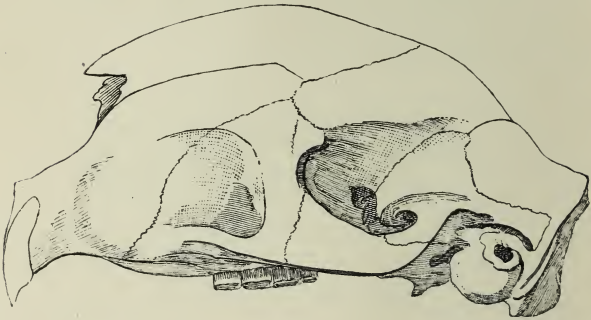


Fig. 118.—Insectivorous dentition; skull of Mole, *Talpa europaea*. Dental formula, $\begin{array}{c} 3 \ 1 \ 3 \ | \ 4 \\ 4 \ 1 \ 2 \ | \ 4 \end{array}$.

Carnivora by being prismatic in form ; their cusps bear some resemblance in shape to those of Carnivora, but are still more sharp and pointed. The rest of the teeth are often difficult to class in the usual divisions ;



A



B

Fig. 119.—Dentition of Rodents. *A*, Porcupine, *Hystrix cristata*, gnawing a piece of wood with its incisors. *B*, Skull of Porcupine, showing sharp-edged incisors, and molars $\begin{smallmatrix} 4-4 \\ 4-4 \end{smallmatrix}$.

but the molars are sufficiently characteristic. The teeth of insectivorous Bats, and of insectivorous Marsupials, resemble in type the teeth of the order Insectivora (hedgehogs, moles, and shrew mice).

Dentition of Rodents.—A very interesting type of dentition is that of the Rodentia, characterized by the great development of the incisors. These grow from permanent pulps; that is to say, they

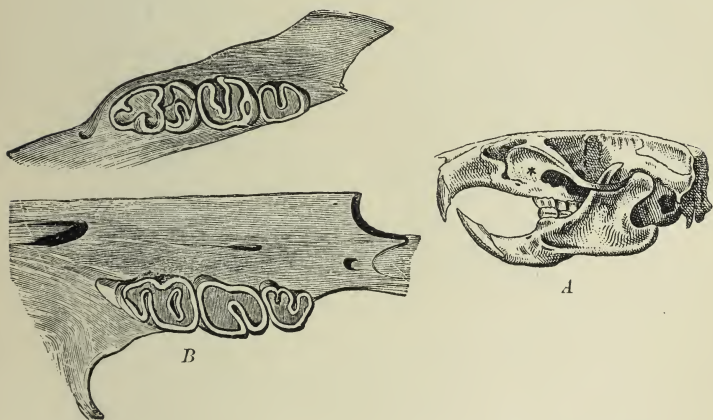


Fig. 120.—A, Skull of Rat, with sharp-edged incisors, and molars $\begin{smallmatrix} 3-3 \\ 3-3 \end{smallmatrix}$. B, Molars of Black Rat (*Mus rattus*), four times natural size, showing enamel ridges left by the wearing down of the teeth.

keep on growing all the time, an arrangement which provides for the great wearing down of the teeth resulting from the gnawing habits of the animals, from which they receive their name. One consequence of this is, that if rats, *e.g.*, are kept in cap-

tivity, their teeth grow inconveniently long, through want of use, and may even cause the death of the animal by penetrating the opposite jaw. Hence a tame rat, if not allowed at large, should be supplied with a piece of wood to gnaw at. The outside edge of

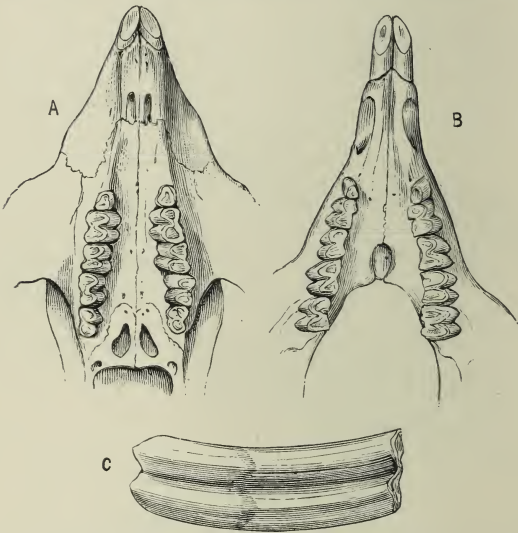


Fig. 121.—Rodent dentition of a Marsupial, the Wombat, *Phascolomys Wombat*. Dental Formula, $\frac{1\ 0\ 1}{1\ 0\ 1} \begin{smallmatrix} 4 \\ 4 \end{smallmatrix}$; incisors and molars both growing from persistent pulps. A, upper jaw; B, lower jaw; C, single molar.

these incisors is protected by hard enamel, while the inside edge is not; hence the inner edge wears down first, and thus the outside edge is always kept very sharp. Similar sharp edges of enamel are maintained on the molars by the presence of edges of enamel,

resulting from the partial wearing down of the tooth, which has at first a very thin crown of enamel; and in some rodents the molars as well as the incisors grow from permanent pulps. The dentition of a Rat consists of incisors and molars only, the former $\frac{1-1}{1-1}$, the latter $\frac{3-3}{3-3}$, with a long gap between them. The Hares and Rabbits have additional incisors and additional pre-molars. The teeth of the Rat present the most highly specialized instance of the rodent type. It will be noticed that they are much reduced in number compared with those of most mammals. It has been suggested that the number of mammalian teeth is primitively 44, this number becoming reduced in highly specialized types of dentition.

There are rodents among the marsupials. The teeth of the Wombat are shown in fig. 12; the incisors differ slightly in structure from those of the true rodents, but are of similar type. There is also a rodent type among the Lemurs, namely, the Aye-aye, *Cheiromys*, of Madagascar. This, like the Australian Wombat, supplies in its native country the place of true rodents, which are not found there.

<i>Sub-kingdoms, or Phyla.</i>		<i>Classes.</i>		<i>Sub- classes</i>
PROTOZOA	{	PROTOZOA	{ Rhizopoda Infusoria	
		CœLENTERATA	{ Porifera Actinozoa	
			{ Hydrozoa Ctenophora	
ECHINODERMATA	{	Crinoidea	{	
		Asteroidea	{	
		Echinoidea	{	
VERMES	{	Holothuroidea	{	
		Platyhelminthes	{	
		Nemathelminthes	{	
		Annelida	{	Chaetopoda Gephyrea Hirudinea
		Rotatoria	{	Entomostraca Malacostraca
ARTHIPODA	{	Crustacea	{	
		Arachnida	{	
		Prototracheata	{	
		Myriopoda	{	
		Hexapoda	{	Included under the name Tracheata

Included under the name of CHORDATA.

Included under the name of
Craniata, in distinction from
Amphioxus.Included under the
names ofBranchiate
Vertebrates, or
Anamniota, or
AnallantoideaIncluded under the
names ofAbranchiate
Vertebrates, or
Amniota, or
Allantoidea

Lamellibranchiata
Gasteropoda
Cephalopoda
Polyzoa
Brachiopoda

((Genus *Balanoglossus*)

Larvacea
Thaliacea
Asciacea

Acrania or Cephalochorda
(one genus only, *Amphioxus*)

Pisces } Ichthy-
Amphibia } opsida

Reptilia } Saurop-
Aves } sida

Mammalia

METAZOA

MOLLUSCA

MOLLUSCOIDA

ENTEROPNEUSTA (or
HEMICHORDATA)TUNICATA (or
UROCHORDATA)

VERTEBRATA

EXAMPLES OF THE USE OF CLASSIFICATION. (No. 1.)

1. Bell *Animalcule*, *Vorticella microstoma*.

<i>Identified as belonging to</i>		<i>Why identified as belonging there.</i>
SUB-KINGDOM	Protozoa	Unicellular in the adult stage. (Thus distinguished from all the Metazoa.)
CLASS	Infusoria	Not amoeboid, but possessed of a fixed outline. (Thus distinguished from Rhizopoda.)
ORDER	Ciliata	Appendages in the form of cilia. (Thus distinguished from the Flagellata, provided with a long flagellum.)
SUB-ORDER	Peritricha	Cilia restricted to an adoral zone. (Thus distinguished from Holotricha, uniformly ciliated, and from Heterotricha, e.g. <i>Stentor</i> , with adoral ciliated zone in addition to cilia distributed over the rest of the body).

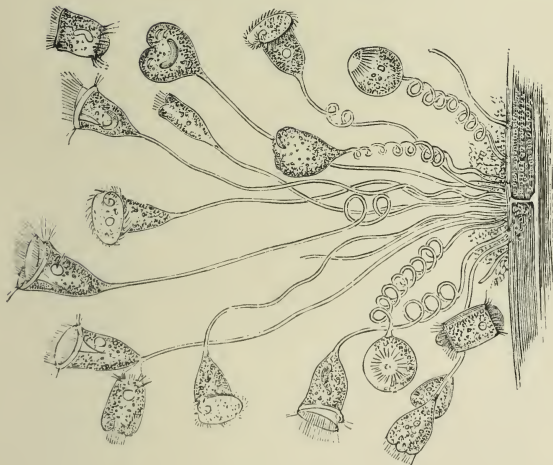


Fig. 122.—A group of *Vorticella*, the Bell Animalcule.

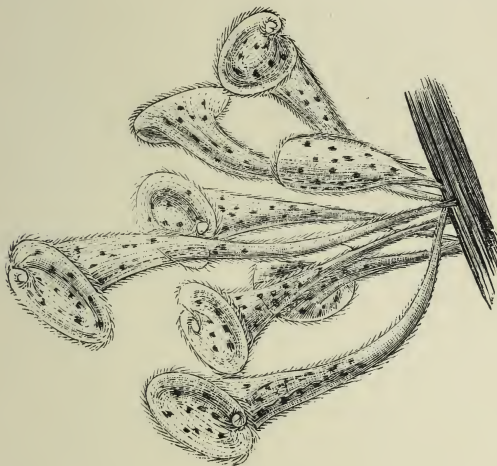


Fig. 123.—A group of *Stentor polymorphus*, for contrast with the former.

EXAMPLES OF THE USE OF CLASSIFICATION. (No. 2.)

2. Common Frog, *Rana temporaria*.

Identified as belonging to

Why identified as belonging there.

SUB-KINGDOM	Vertebrata	Possessing a highly developed central nervous system, dorsal and longitudinal in position, and protected by a skeletal structure (spinal column). The latter is preceded in embryonic life by a notochord, usually more or less obliterated in the adult by the growth of the spinal column. The central nervous system, dorsal in position, has a skeletal protection, the skull and spinal column. (Thus distinguished from all other animals.)
CLASS	Amphibia	The adult is an air-breathing animal. (Thus distinguished from fishes.) There is a larval stage, which has gills adapted for aquatic respiration. The skull has two condyles, the skin is without scales, and the embryo has neither amnion nor allantois. (Distinguished from Reptiles by each of these points.)
ORDER	Anura	Tail absent in adult. (Thus distinguished from the Newts, Urodela.)
SUB-ORDER	Oxydactylia	Pointed fingers and toes, and a movable tongue. (Thus distinguished from the Anura of the New World.)
FAMILY	Ranidæ	Especially adapted for jumping, by the great length of the hind legs. (Thus distinguished from Toads.)

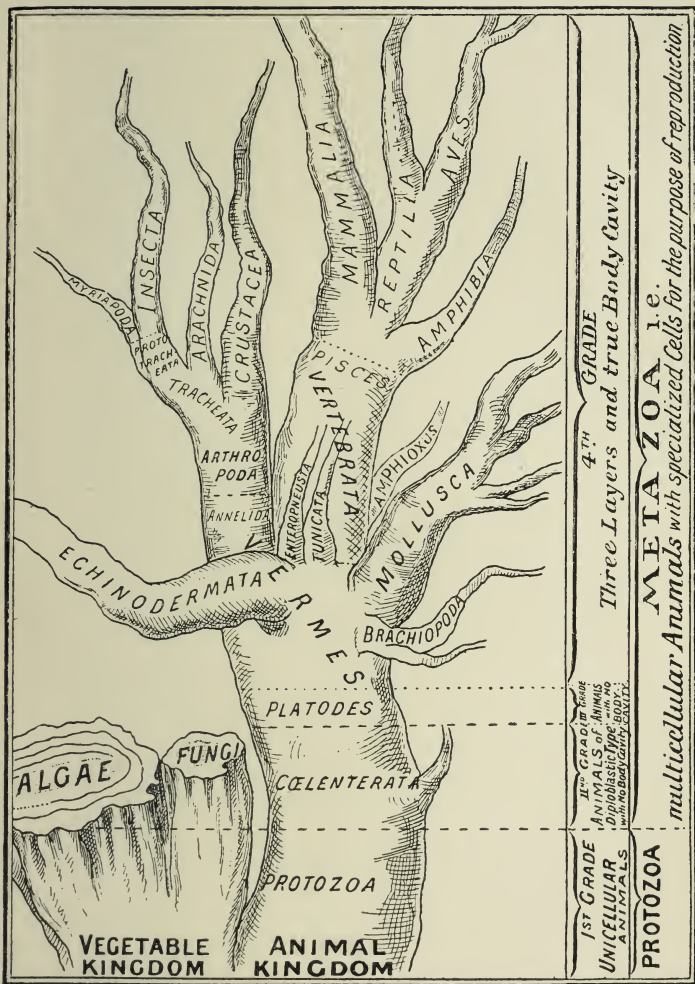


Fig. 124. **DIAGRAM** indicating the relationship of the **CHIEF SUB-DIVISIONS** of the **ANIMAL KINGDOM**

PART III.
ADVICE TO STUDENTS.

CHAPTER I.

THE USE OF BOOKS.

THE following course of study is recommended to the student who desires to begin the study of Zoology in earnest.

The London Science Class Books of Zoology, by Prof. Alexander McAlister, two vols., on Invertebrata and Vertebrata, price 1s. 6d. each (Longmans), afford a short outline of the science, which may with advantage be fixed in the memory by once or twice reading, before proceeding to the study of larger works; while the *Primer of Zoology*, by Prof. A. Newton (S.P.C.K., Manuals of Elementary Science, price 1s.), explains the elements of Zoology in a very clear and interesting manner, and will teach the student how to handle facts intelligently from the very beginning. These little volumes should be thoroughly mastered before attempting to read larger works; and the reader should try to make acquaintance with as many as possible of the animals named in these books.

A few books on natural history should then be read, before meddling with text-books of comparative anatomy. The Rev. J. G. Wood's various popular works, *Homes without Hands*, *Common Objects of the*

Sea-shore, etc., may be recommended for the younger reader, and Miss Buckley's charming books, *Life and her Children* (Stanford, 1880; 6s.) and *Winners in Life's Race*; while for the adult reader, Sir John Lubbock's book on Ants (*Ants, Bees and Wasps*: International Science Series; Kegan Paul, 5s.), and Darwin's book about Earthworms, will give an insight into the best ways of studying animals.

Then study some of Darwin's books; *Plants and Animals under Domestication* is the one most suitable to begin with, for the simple reason that the types described in it are familiar to everybody, and it therefore requires no special zoological knowledge to understand the reasoning presented. After that, the *Origin of Species* should be read. Dr. Andrew Wilson's interesting popular work, *Chapters on Evolution*, although published some time ago, may be read with advantage by those who find the *Origin of Species* too difficult to understand at first reading. Next, it will be well to go through all these books again, with the aid of Claus and Sedgwick's *Text-book of Zoology*, looking up in the latter the structure and place in classification of the chief animal types mentioned, so as to work the knowledge of theory in with the knowledge of systematic Zoology. In this book, too, will be found some discussion of Darwin's views. This work should be used as a book of reference by the elementary student, systematic study of it being a possibility only for those who have made considerable progress in the study of Zoology.

An invaluable book for the adult student and one interesting even to the general reader, is the *Study of Animal Life* (Murray: University Extension Manuals, 1892, price 7/6) by J. A. Thomson. It explains the most advanced questions of zoological science in a clear and interesting manner, and with a charm of style unusual in the writings of scientific specialists.

At least a year should be devoted to the above course of reading, premising that the reader has other occupations besides the study of Zoology. Having now gained some idea of what zoologists "are driving at," as the popular saying is, the reader will be ready to begin work. Huxley and Martin's *Lessons in Elementary Biology*, taken in companionship with Howes' *Atlas of Biology*, will show the student what are the methods of accurate observation by which the compendious knowledge given in text-books has been arrived at; and if he has it in him, they will fetch out his instinct for practical work, and induce him to obtain specimens and start on the course of dissection which is described. If he finds he has an aversion for this, he will be able to ascertain whether it arises from a dislike to handling "corpses," however small, or (as is quite as likely) from mere idleness and want of love of accuracy, by noticing if he gets on any better with the vegetable forms described in the same books. If this is not the case, he may make sure that he is merely too idle to make a zoologist. For the most industrious student, how-

ever, if the work involves learning the use of the microscope for the first time, the course is long and tedious, even with the assistance of a teacher, and the self-taught student can only expect to master parts of it. But to master any part of it is a training in accuracy which will be useful afterwards, for it will teach the student to leave no part of any specimen unexamined or unexplained.

A very necessary supplement to the book just named, will be found in T. Jeffery Parker's *Lessons in Elementary Biology*. This is a book modelled somewhat on the general plan of the older volume; but the plants and animals described in it are more numerous, and for the most part not the same. The arrangement of the book is so complete, and its explanations of the theoretical part of biological study so lucid, that the student cannot possibly do without it, especially as it has the merit of being illustrated, so that it does not, like the other volume, require an atlas to explain it. The principle on which the teaching of both these volumes is based, is expressed in the maxim which has been already quoted in the chapter on classification, that "Natural groups are best described, not by any definition which marks their boundaries, but by a type which possesses in a marked degree all the leading characters of the class." The elementary student is made thoroughly acquainted with the character of certain typical organisms, before being introduced to the names and definitions of classes—a mode of teaching by which

parrot-work is rendered impossible. The chief advantage of beginning with this course of study, however, is that it is now generally made a preliminary to all teaching in Zoology, besides being insisted upon as a preliminary subject in many examinations, so that in much that is now written on subjects connected with Zoology, a knowledge of the facts included under the heading of elementary biology is usually presupposed. But students who cannot find opportunity for thoroughly mastering this course of study, must not allow themselves to be disheartened. "All roads lead to Rome," and any branch of Zoology will do to begin upon, provided only that it is carefully studied: a comparison of mammalian skulls, or of molluscan shells, will make just as good a beginning of knowledge as a course of "biology," if the *comparison* is not forgotten in mere *collecting*. A mind possessed of any originality will be independent of any given course of study; nevertheless, for the reasons above given, the student should try to master as much as possible of the lessons included in the books named above.

With regard to microscope work, it may be suggested that local dealers in microscopes and other scientific instruments are often acquainted with some one in the same district, who is able to help, advise, or teach the beginner; while the various correspondence classes now established give instruction for examination purposes, in Zoology or in the course of study indicated by the two works just named, which

may be useful to the isolated and self-taught student, however unlikely to enter for any examination.

A list of standard Zoological text-books is given at the end of this chapter. It is not intended to be exhaustive, but to be initiatory; and various well-known books have therefore been omitted from the list.

The student who wishes to make a further acquaintance with the literature of Zoology, will find useful lists of books in Swan Sonnenschein's *The Best Books and Reader's Guide*, section "Zoology," 1891 and 1895.

Having mastered as much as it is possible of the above-named course of elementary biology, the reader should procure Jeffrey Bell's *Comparative Anatomy and Physiology*, and study it carefully; not only because it explains the most advanced problems of Zoology, and the most advanced ideas about them, in a very terse and clear manner, but also because it embodies some of the views of Prof. Ray Lankester, which occupy a most important place in the history of morphological science. After this, the student cannot do better than turn back and read these books over again; by that time he will begin to know how to use a text-book of Zoology.

It must of course be understood that no mention has been made of the vast field of literature which marks the actual progress of zoological science, and embodies the results obtained by workers whose very names are unknown, except to those who are fairly acquainted with the science. The references given in some of the

larger books recommended here will give the reader an introduction to literature of this kind, which he should look at when opportunity affords, although he may not understand it. I suggest this, because I think it is sometimes well for the elementary student to glance at papers, drawings, and diagrams which are intended only for the advanced student, just in order to see the *form* in which original work is turned out. For this purpose, the reader may look at the volumes of the *Quarterly Journal of Microscopical Science* (Churchill), or the zoological papers included among those published by the Royal Society.

New books come out from time to time. The student should be on the look-out for such of them as may be useful. Reviews of them may usually be found in the pages of *Nature*, as well as other information useful to the zoologist. *Natural Science*. (Rait Henderson : price 1s. monthly) will also be found useful in a similar way.

It must be remembered, however, that even the best and the newest *books* on Zoology are always a little behind the day. All new discoveries, observations, and theories are recorded in essays communicated to the various learned societies ; and it is often years before they are embodied in text-books. The student whose knowledge is as yet limited to text-books is therefore in a position similar to that of a child at school, who knows the history of England, but is as yet ignorant of politics, and unacquainted with newspapers, to say nothing of blue-books. It is an advantage for

the student to realize at the outset where the *news* of zoological science is recorded, and how vast a literature it affords. The student who takes the advice already given, and glances over a few specimens of this literature, will not make the mistake of looking for information in popular magazine articles, or of supposing that he will know the whole of Zoology when the first text-book is fairly mastered. Moreover, the touchstone of a student's capabilities is found in his first impression, on seeing the results of first-rate work, of the vast distance between his own ignorance and the knowledge possessed by other people. To the idler, it is a disappointing and depressing experience: to the industrious student, on the contrary, the size and grandeur of the field of possible knowledge that lies in front, is an inspiration and a delight.

It need hardly be said, that all the advice given in this chapter, is addressed to those who are not able to obtain personal and systematic teaching. After taking the bold step of recommending beginners to glance at (*not* to try to study) essays such as those in the *Quarterly Journal of Microscopical Science*, etc., which are necessarily beyond their comprehension, a word of caution must therefore be added. For self-taught students it is necessary to guard against the mistake which more than fifty per cent. of them make, of taking up books or essays which are quite beyond their comprehension, and reading on and on in a brown study, without realizing that they are not

understanding what they are reading. This, however, is less apt to happen in reading Zoology than in reading general subjects, for any failure in attention is quickly checked by the resulting inability to understand the diagrams with which all important books or essays are illustrated, and which of course form the most valuable part of them.

A few words must be said about the manner, as well as the matter, of reading. The student should at first make it a rule to write out from memory a short abstract—the shorter the better—of the chief points of every chapter of the book he is reading; and when he has finished the volume, a short abstract of the whole. These abstracts should be corrected by reference to the volume, and unless the book is one that he can purchase and keep, should be then copied successively into a large note-book, and headed by the exact title of the book, its date, name and address of publisher, and price. In this manner a manuscript volume of reference will soon be formed, invaluable to the writer of it.

The student must of course make a point of ascertaining the meaning of every new word he meets with, including proper names. The meaning of these is frequently such as to assist the memory in retaining a description of the animal; but even if all of them were, as some of them are, far-fetched or foolish allusions to classical legends, yet the habit of passing *words unexplained* is such a bad one, that rather than run any risk of falling into it, it would be better to spend a

little time over the misapplied learning which has been mixed up with zoological nomenclature. A classical education is not necessary for this purpose ; a knowledge of the Greek alphabet as well as of our own, with industry enough to use a dictionary, will be sufficient in order to ascertain the meaning of the vast majority of scientific names. Two golden rules, if followed, will do the utmost that can be done to make the reader independent of any teaching but his own. The first is, never pass a word without making sure that you know its meaning and pronunciation. The second is, never read a description of any animal which you have not hitherto seen, without making a note, either in your mind or in your note-book, that you must search, in field or museum, or illustrated atlas, till you find the thing named, and that then you must compare it with what you have read about it.

The student whose time or money is limited, should look over the other books I have named, in some library, and buy for home use Parker's *Elementary Biology*, and Jeffrey Bell's *Comparative Anatomy and Physiology*, which two volumes will afford him the utmost possible amount of real knowledge in the smallest possible space. But those who already have some general knowledge of Zoology, derived from popular literature or from collecting, will find Claus' *Text-Book of Zoology* the most useful, because it names a large number of genera, and thus enables the student who already knows a number of kinds by sight and by name to fit them into their right places in systematic Zoology.

A number of the standard works named in this volume are to be found in the reference libraries of our larger cities, where they may be consulted by students whose means do not permit of purchasing them; and all may be seen in the library of the British Museum, access to which may be obtained by adults under certain conditions, and on giving suitable references. Information as to the rules to be observed can be obtained from the principal librarian.

Meanwhile, whatever may be the use made of books, no opportunity for "naturalizing," or for practical work, should be let slip. The student should keep a note-book, and enter in it a drawing and a description of every fresh "beastie" he comes across, taking note of its place and season of appearance, habitat and food, if he can ascertain them, and name and place in classification when he has looked these out. For this it is not necessary to live in the country; in London numbers of different kinds of butterflies and birds may be seen. Even in the still less promising wilderness of a manufacturing town, the same visitors are found, and I have seen a dozen different kinds of winged insects caught on a windy day in the trap undesignedly afforded by an open rain-water cistern. Moreover, for those who live in towns, the annual holiday now enjoyed by almost every one, affords opportunity for the study of natural history elsewhere. It must be remembered that it is not necessary to get *rare* specimens in order to study Zoology; but to get common kinds, and learn their structure well. The

search after rare specimens is sometimes mere trifling, and the searcher equally ignorant of the nature and structure of the prized specimen as of that of common kinds; the connoisseur in rare insects or shells is no more necessarily a zoologist, than the connoisseur in rare books is necessarily possessed of learning. The study of local Zoology, however, will not carry the student very far in investigating the animal kingdom; nor will the study of specimens in local museums, except perhaps in our largest towns; but an occasional visit to the Natural History Department of the South Kensington Museum will be possible to most people, and will be an invaluable experience for the provincial student. Those who have any taste for Zoology, however, will find specimens to learn from somewhere or other; and those who have no taste for the science should turn their energies elsewhere. I must, however, impress it on the reader, that a real acquaintance with Zoology can only be gained by practical work or out-door observation: Zoology cannot be learnt from books alone.

Companionship in every pursuit adds to the pleasure of it; and in nothing is it so necessary as in studying a difficult subject, when two heads are often better than one, and the help of more experienced workers is a necessity. There are now in many districts local Societies for the popular study of microscopic or zoological science. These may usually be heard of, through their reports, at the Free Library of the nearest large town; and the names of some of the more ambitious among them may be found in the *Year-Book of the*

Scientific and Learned Societies of Great Britain and Ireland (published annually: Charles Griffin & Co., Exeter Street, Strand). In the same volume useful particulars may be found regarding the various learned societies organized for similar purposes.

Although of late years the tide has set strongly in favour of biological science, and the solitary naturalist is no longer regarded, even in rural districts, as quite a lunatic, yet frequently he *is* solitary, and meets with more prejudice than sympathy; and I cannot help taking the opportunity of recommending to that injured being, the solitary naturalist, two books of a totally different class from any in my previous list—Smiles' *Life of Dick of Thurso*, and his *Life of Edward*, the Scottish naturalist, the record of whose social troubles in the pursuit of science has probably raised at once the laughter and the sympathy of many kindred souls. The naturalist who looks upon animals with the eye of a philosopher rather than of a collector, will find passages that are of interest in the *Life of H. D. Thoreau*, the pupil of Emerson (by H. S. Salt: Bentley & Son).

University Extension Lectures. Students in country places may obtain much help from "University Extension Lectures." Any small band of students who desire instruction in a given subject, can now obtain a course of lectures, more or less popular, on application to one of the universities. The example of Cambridge, in providing lectures of this kind, has now been followed by other centres of learning

throughout Great Britain. Full information about lectures of this kind may be obtained from the *University Extension Journal* (Macmillan & Co.: price 2d., monthly).

Those who intend to apply for a course of lectures on Zoology should bear in mind that it is usually desirable to apply to the *nearest* of the great centres of education, so as to bring themselves into touch with any enthusiasm for the subject that may exist in their own neighbourhood.

Science and Art Department Classes. It should not be forgotten that, so far as regards Biology, teaching of an elementary kind is now supplied in connection with the Science and Art Department.

Biological Stations. The advanced student should obtain particulars regarding the various Biological Stations which have been established on the British coast for the study of marine biology. Students of sufficient merit may obtain the privilege of working in these laboratories, on payment of moderate fees; and teaching may in some cases be obtained. Specimens which will be useful to the advanced student may be purchased from some of these laboratories. Biological stations exist at Plymouth, St. Andrews', Port Erin, Isle of Man, and on the Island of Cumbrae, Frith of Clyde; while similar stations devoted to the hatching of fish exist at Dunbar, Grimsby, and Brodick, Isle of Arran. Messrs. Sinel & Horsell's laboratory, at Jersey, is referred to elsewhere (p. 332).

Books. The following are books especially recommended for study:—

1. *Elementary Biology*; Huxley and Martin: edited by Howes and Scott: Macmillan: 1888: price 10s. 6d.
2. *Atlas of Practical Elementary Biology*; G. B. Howes: Macmillan: 1885: price 14s.
3. *Lessons in Elementary Biology*; T. Jeffery Parker: Macmillan: 1891: price 10s. 6d.
4. *Elementary Text-Book of Zoology*; Claus, edited by Sedgwick: Swan Sonnenschein: Two vols., 1884, 1885 last edition, 1892, 1893: price 21s. and 16s.
5. *Comparative Anatomy and Physiology*; F. Jeffrey Bell: Cassell: 1885: price 7s. 6d.
6. *Elements of the Comparative Anatomy of Vertebrates*; Wiedersheim: edited by W. Newton Parker. Macmillan: 1886: price 12s. 6d.
7. *Encyclopædia Britannica*; Zoological Articles contributed by Lankester, Sollas, Von Graff, Hubrecht, Bourne, and Herdman. London: Adam and Charles Black: price 12s. 6d.
8. *Osteology of the Mammalia*; Flower and Gadow: Macmillan: 1885: price 10s. 6d.

For the student who wishes to begin practical work in dissection, the following are also necessary:—

9. *Course of Instruction in Zootomy* (Vertebrates). T. Jeffery Parker: Macmillan: 1884: price 8s. 6d. (Lamprey, Skate, Cod, Lizard, Pigeon, Rabbit.)
10. *Junior Course of Practical Zoology*; Marshall and Hurst: Smith, Elder: 1887: price 10s. 6d. (Rabbit, both skeleton and soft parts; Pigeon; Dog-fish; Snail; Leech; Liver-fluke; Hydra; Vorticella; Paramœcium.)

The following are works which the advanced student may use for reference:—

11. *Outlines of Zoology*. J. A. Thomson. Young J. Pentland: 1892: price 12s. 6d.
12. *Elements of Embryology*; Foster and Balfour: Macmillan: 1883: price 10s. 6d.

13. *Introduction to the Study of Embryology*. A. C. Haddon. Griffin: 1887: price 18s.

14. *Forms of Animal Life*. Rolleston and Jackson. Clarendon Press, Oxford: 1890: price 36s.

15. *Text-Book of Comparative Anatomy*; Dr. Arnold Lang, Preface by Prof. Ernst Haeckel: London: Macmillan & Co., vol. i.: 1891: price 17s. net.

16. *The Cambridge Natural History*. Edited by Harmer & Shipley. Macmillan: vol. iii. (published first): "Molluscs and Brachiopods": 1895: price 17s. net.

17. *Introduction to the Study of Mammals, living and extinct*. Flower and Lyddeker; A. & C. Black: 1894: price 12s. 6d.

18. *Dental Anatomy*. Tomes; Churchill: 1882: price 12s. 6d.

The following may also be recommended:—

19. *Zoology for High Schools and Colleges*; Packard: Holt, New York.

20. *Handbooks of Vertebrate Dissection*, 3 parts; Martin and Moale. Macmillan, New York: 1881, 1884: price \$2.10.

21. *Lectures on the Darwinian Theory*; A. Milnes Marshall: London, Nutt: price 6s.

22. *Introduction to Palæontology*; H. A. Nicholson. Edinburgh, Blackwood: 1887: price 3s. 6d.

23. *Manual of the Mollusca*; S. P. Woodward: 1889: price 6s. 6d.

24. *The Life and Letters of Charles Darwin*.

[The student is recommended also to make some acquaintance with the *Reports of the Challenger Expedition*, the various articles on vertebrates in the *Encyclopædia Britannica*, which are not included in the volume already named; the volumes on various zoological subjects which have appeared in the *International Science Series* (Kegan Paul), and the current publications of the learned societies established for the study of Zoology and of its various departments, such as ornithology and entomology. Those of the South Kensington Science

Handbooks (Chapman & Hall, 193, Piccadilly) which relate to various departments of Zoology, will also be found useful. The student who requires a popular book on Natural History will find much that is useful in Cassell's *Popular Natural History*, last edition, edited by P. Martin Duncan, F.R.S., or in Warne's *Royal Natural History*, edited by R. Lydekker, F.Z.S.

For reference regarding questions of theoretical physiology which may puzzle the student of Zoology, the article on Physiology in the *Encyclopædia Britannica*, and McKendrick's *Text-Book of Physiology*, afford information in a readily intelligible form. Information on details of histology should be obtained from Quain's *Elements of Anatomy*, vol. i., part ii. *Histology*, by E. A. Schäfer (10th ed., 1893; Longmans: price 6s.) The advanced student who requires information regarding methods of preparing specimens for the microscope, may consult *The Microtometist's Vade-Mecum: a Handbook of the Methods of Microscopic Anatomy*; by Arthur Bolles Lee. 2nd ed. Churchill: 1890: price 8s. 6d.

CHAPTER II.

PRACTICAL WORK.

THE mere reading of books is not by itself of much good to the elementary student; a knowledge of animals cannot be obtained except by seeing them. If the student wishes to understand the internal structure of animals, he will have to learn to dissect them; he may, however, wish only to study the habits of animals, and make friendly acquaintance with them in the live state. He should make up his mind what he wants to do: whether his ambition is in the direction of becoming a comparative anatomist or a naturalist. Of course he *may* be *both* (as Abernethy's patient suggested, when told that a man of forty is either a physician or a fool); but the presumption is against it, when one considers the contradictory tendencies of the two—for the naturalist rejoices in keeping his animals alive, while the enthusiastic comparative anatomist wants to dissect them as soon as possible. In making the choice of your own line, do not forget that Darwin was pre-eminently a naturalist. It was by watching the natural conditions of animal life and of plant life, and sometimes the interaction of the two, that he did more to enable us to understand the truth about living creatures than has ever been

accomplished by the specialist in the mere study of structure, however accurate and learned. There is still much to be learnt by outdoor observation, about the habits and distribution even of common animals. Such observation requires no apparatus but a pair of eyes, and no learning but common sense; and it adds to the health of the observer, which all indoor studies, on the contrary, tend to ruin. These facts should be borne in mind by students who possess a taste for natural history, before they decide to confine their energies to the grooves indicated to them by textbooks and examination papers—grooves which will of necessity be followed, for professional purposes, by many who have no such tastes, but which ought not to limit the energies of those who have a real aptitude for zoological studies.

If the student decides, however, to begin a course of dissection, he may refer to the books named on p. 316; but he will need to make good use both of hands and eyes, if he is to learn much about dissecting without the assistance of a teacher. Those whose tastes run in this direction, however, will usually have some acquaintance who can give them help. The student should bear in mind, in beginning practical work, that the dead animal body, whatever its kind, should be regarded with a certain reverence, as the physical expression of that wonderful uncomprehended thing we call Life. The study of the animal body, undertaken in a right way, brings us into the presence of the great problems of our exist-

ence—the origin of man, the origin and nature of life, the past and the future of our kind, and of ourselves. The student whose work is dignified by thoughts of these things, not degraded by a coarse inquisitiveness, may fitly and rightly undertake the work of dissection.

In procuring the material for dissection, the thoughtful student will hesitate to take life for the mere gratification of curiosity. There are often sick or superfluous domestic animals which from motives of humanity have to be destroyed; and a thorough study of the dissection of the cat and dog will form an excellent beginning for the student, especially as the two are nearly related, and will give practice in distinguishing the smaller and less striking differences which exist between allied genera. Some of the bones of the first specimen will probably be spoiled in dissection; a second one of each should be got, the bones cleared so far as possible, and then macerated, *i.e.* soaked in water till the remains of the tissues are decayed and can be easily cleaned away. The process may be hurried up by partly boiling the skeleton; but this spoils the colour of the bones. In any case, the use of a little bleaching powder will improve the colour. Great care must be exercised in making sure that none of the bones are lost; ascertain their right position, and wire them together. Rats and mice may easily afford the student's next lesson. These animals, which by their rapidity of multiplication would otherwise starve us out, have to be destroyed, therefore use them

for dissection, and spare others that are harmless. It is said that the authors of a well-known contribution to the literature of original research in histology used as their chief material the mice caught in their own house. This example of careful economy of animal life is one worthy to be recollected.

Many of the invertebrate specimens required may be selected on a similar principle to that already recommended, *i.e.* avoiding needless destruction so far as possible. The cockroach that infests the kitchen may be easily induced to decree its own execution in the fashion it prefers, like the famous Duke of Clarence, if you set—not “a butt of malmsey wine,” but a flat dish filled with plebeian beer; in this it may be trapped by dozens. The snails that devastate your cabbages may be picked out of the bucket in which the gardener drowns them, and used for purposes of science; and the common cabbage caterpillar, and many other garden pests may be got rid of in the same way. Drowning, or the use of ether or chloroform, are the most humane ways of disposing of almost every animal. In using either of the two latter, soak a sponge with it, and place it with the animal under a jar or bell-glass well fitted down.

The student may either begin, as directed here, with the larger animals, or begin with the smaller invertebrate forms, and work onwards to the higher types. The former plan has the advantage of beginning with structures big enough to be seen without difficulty. The advantage of the latter is, that the sen-

sitive student has an opportunity of gradually mastering the repugnance felt to handling dead organisms, instead of having to conquer it all at once. It must be remembered, however, that this repugnance is merely physical squeamishness, and should, therefore, not be too much indulged. Let the student be fastidious about the means by which his material is procured, avoiding all cruelty, but learn to conquer fastidiousness in other respects.

Quite as necessary to the zoological student as the arts of reading and writing, if not more so, is the art of drawing. The student not only may, but *must*, learn to copy diagrams accurately from books, and to make a clear and plain sketch of every animal, skeleton, dissection, or microscope preparation, and also a diagram (*i.e.* a conventional representation, in outline, map, or section) of structures which are too complicated for all their parts to be represented in detail. Pencil, coloured chalk, pen and ink, colours, and neutral tint, any or all of them, will be found useful. Diagrams and drawings should be entered in a note-book or sketch-book kept for the purpose, with a description of the specimen they were copied from, and a note of the date and place at which it was found, or of the museum in which it has been studied, as the case may be.

In dissecting cockroaches and caterpillars, it will be necessary to use a lens. In order to see the structure of tissues, a microscope of good magnifying power is required. In learning its use, books may be con-

sulted;¹ but it is best to have some practical lessons from the dealer you buy it of, or the friend you borrow it from. Information as to where a good microscope may be bought is given below.

Microscope preparations may be bought of many different dealers, from whom almost any desired object may be obtained. But many mounted objects are of very little value, being prepared merely with a view to looking pretty, while all the essential parts are destroyed, or so altered by reagents that they are not in the least like what they were in the fresh state. This does not apply, however, by any means to all.

The following is a list of some of the firms from which microscope preparations may be obtained:—

Aylward, 164, Oxford Road, Manchester.

Baker, 244, High Holborn, London.

Enock, 11, Parolles Road, Miranda Road, London, N. (For insects especially.)

Hinton, 12, Vorley Road, Upper Holloway, London, N.

Hume, 1, Lothian Street, Edinburgh.

Medical Supply Association, 12, Teviot Place, Edinburgh.

¹ One or both of the volumes named in the list of books that has been already given (Nos. 1 and 10) may be used as a guide in practical work.

Appendix in Huxley & Martin's *Elementary Biology*. See also *Encycl. Brit.*, art. "Microscope," by W. B. Carpenter. Among older books, Dr. Carpenter's *Microscope and its Revelations*, and *How to Work with the Microscope*, by Dr. Lionel S. Beale, may be named as likely to be useful for reference. Most good firms now publish a little pamphlet of directions, giving full details regarding lenses, etc., for distribution with their microscopes.

Vial, H., Crediton, Devon. (Physiological slides.)
Ward, University Dépôt, Oxford Road, Manchester.
Watkins & Doncaster, 36, Strand, London, W.C.
Watson, 313, High Holborn, London, W.C.
West, 15, Horton Lane, Bradford.

The above, given in alphabetical order, are a few among many firms from which microscope preparations can be obtained. For the names of others, and for information regarding microscopes and other apparatus, the student may with advantage consult the advertisement pages of *Nature*, and of *Hardwicke's Science Gossip*. In addition to those already named, Messrs. Sinel & Horsell, Jersey Biological Station, may be specially recommended. The following firms may be named as supplying first-rate microscopes, while they also supply zoological slides for the microscope, and instruments and apparatus of various kinds :—

C. Baker, 244, High Holborn, London.
R. and J. Beck, 68, Cornhill, E.C.
F. E. Becker & Co., 34, Maiden Lane, Covent Garden, London.
H. Crouch, 66, Barbican, London, E.C.
Fannin & Co., 41, Grafton Street, Dublin.

Good microscopes may also be obtained from J. Swift & Sons, 43, University Street, Tottenham Court Road, London. Second-hand microscopes may be obtained from Baker, or from Sands, Hunter & Co., 20, Cranbourn Street, Leicester Square, London, W.C., and from the Medical Supply Association, 12, Teviot Place, Edinburgh, which also supplies microscopes to students on an advantageous system of hire.

The best microscopes obtainable are those made by Carl Zeiss, of Jena; and excellent instruments are supplied by other German makers.

Before purchasing either microscope or microscope preparations, however, the student should obtain price lists from several firms at least, and should not attempt to obtain either second-hand, unless he has considerable experience in microscope work. Improvements are being constantly introduced, and prices constantly lessened, so that the newest instruments and apparatus are usually the cheapest as well as the best.

The following may be named as dealers in zoological specimens, such as crayfish and amœbæ, and in skeletons, etc. :—

T. Bolton, 62, Balsall Heath Road, Birmingham.

F. S. Leach, 3, Great St. Andrew's Street, Bloomsbury, London, W.C.

R. G. Mason, 24, Clapham Park Road, Clapham, London.

The human skeleton, either the whole or separate parts, and the skeletons of the cat, dog, rabbit, pigeon, and frog, may be obtained from the Medical Supply Association, 12, Teviot Place, Edinburgh, and those of many other animals, from Chapman & Hall, Limited, 11, Henrietta Street, Covent Garden, London, W.C.

The reagents necessary for the course of work indicated in Huxley & Martin's *Biology*, may be obtained from several of the above firms.

CHAPTER III.

ANIMALS AS FELLOW-CREATURES.

IF the dead animal body is to be regarded with reverence, still more is the living animal body to be regarded with kindness. The great lesson learnt by the zoologist is that of the fundamental unity of Life: there is something in the smallest creatures which is akin to ourselves; and just as there is always something in their physical structure which is correlative with our own, so also there is something which represents the germ of our highest intellectual and moral faculties. Pleasure and pain, the misery of cold and hunger, the enjoyment of warmth and food, the smallest creatures share with ourselves; and many of the higher ones experience love, friendship, the unselfishness of a parent's duty, and even of a citizen's, precisely as do human beings: possibly in a lesser degree, but not always—for that some dogs have more intelligence and more capacity for a noble friendship than some men, no one will deny who has any wide acquaintance with either species. The study of the animal kingdom, as a whole, ought to impress us strongly with a feeling of kinship to our poor relations, the "lower animals," as they are called. While the

duty of self-preservation compels us to destroy those animals which, directly by their ferocity, or indirectly by their number, endanger our lives—as indeed it also compels us to destroy, by war or judicial penalty, those of our own species who do the same—yet it should be the instinct of a generous mind to spare and to protect those lesser lives which can harmlessly co-exist with our own. In the earlier stages of human life, when man had to battle with the other creatures for his own safety, the hunter was respectable, both because his activity was useful and because it required him to brave danger; but in an old country like our own, where all the dangerous and most of the tiresome animals have been already killed out, the hunting instinct is an anachronism, and its indulgence often a mere puerile affectation. The sportsman is apt to become a similar social nuisance to the wandering botanist, who promptly uproots all plants that are not common. The true naturalist would fain see the energies of both applied elsewhere; these people would be useful in a new colony, where they could extirpate wild beasts, clear forests, and root up poisonous plants; but at home their mischievous activities jar on the lover of nature. The sparrow-hawk and the pussy-cat are no doubt very interesting types of individuality; but it is not a very lofty ambition for human beings to imitate them in the destruction of perfectly helpless and harmless small game. The aim of the naturalist should be to encourage all harmless types of animal life. Nearly every creature can be

tamed by man; the fear of man evinced by most wild creatures is merely the result of their experience and observation, for creatures that have not been used to the sight of human beings evince no fear of them. An interesting experiment on the principle of non-interference as applied to the fauna of our own country was made many years ago by the celebrated naturalist, Mr. Waterton. He did not allow any of the wild animals and birds on his estate to be destroyed. Every one supposed the place would soon be overrun by them; but it was found that the predatory kinds kept the others down, so that there was no inconvenient multiplication of mischievous kinds, and many rare and curious creatures came to live there, finding that they were not molested. It is to be wished that experiments of this kind were more frequent, and the spirit in which they were made more common.

The observation and companionship of healthy and happy animals (*not* shut up in cages) is an everlasting source of fun. Animals of all kinds are always full of frisk; probably because, as Walt Whitman observes, they do not trouble about being "respectable," *i.e.* do not make themselves miserable by centering all their energies on trying to behave exactly like their neighbours. It is quite a mistake, however, to suppose, as some misanthropes do, that animals are any better than *other people*. They would not be nearly so funny or so lovable as they are, if they had not the germ of most human weaknesses. Nobody can doubt

that the peacock is vain, the magpie greedy, the cat lazy, the fox sly, the bull aggressive, the mouse cowardly, and the parrot or the corncrake "fond" (as the rustic saying is) "of the sound of its own voice," any more than they can deny that the dog is faithful, the love-bird constant, and the lion brave. Nobody who has ever had a pet of any sort could be deceived by the stale trick of the old-fashioned moralists, of attributing to man a monopoly of all the vices; and a stable-boy would quickly detect the false art of Swift's final satire¹ on human nature, which owes its form at least as much to the author's want of candour concerning the vices of horses, as to his want of appreciation regarding the virtues of men.

Those who are anxious to study live animals rather than dead ones, will find plenty of interest in the works of the older naturalists, and in the pleasant gossip of many keen observers of country life in the present day. The following books and magazines may be especially recommended.

White's *Natural History of Selborne* necessarily stands first on the list, and is too well known to need further reference. Among text-books, Thomson's *Outlines of Zoology*, already named in the list given on p. 323, must be recommended as the only one that gives evidence of the author's love for living animals, and perception of their merits from a humourist's point

¹ "Gulliver's Voyage to the Country of the Hounhynhym's."

of view. It need hardly be added, therefore, that the book, although suitable for advanced students, does not share the usual dullness of text-books. Dr. Lauder Lindsay's *Mind in the Lower Animals* (2 vols., Kegan Paul, 1879) is a book that should be in the hands of every lover of animals. It will prove a useful antidote to much that has been written in newer books by less humane men, although the author goes much too far in search of the picturesque when he attributes consciousness to decapitated frogs and feeling to plants. The volumes as a whole present a masterly summary of the proofs constantly given by animals that their minds as well as their bodies are of kindred nature with our own. The author gives a useful list of literature bearing on his subject. Among current periodicals, the *Animal World*, monthly organ of the R.S.P.C.A. (Partridge), and *Nature Notes*, the organ of the Selborne Society (published by Sotheran & Co., London), sometimes contain paragraphs which are of interest to the lover of animals.

It is worth while to study the traces of the original relations between man and beast that exist in fables and folk-lore. The peasant of a remote age, living in constant warfare with wolf or fox, appreciated their traits of character none the less truly, because it was his way to express what he knew of them in a "yarn" rather than a scientific treatise, and to point a sly moral at the same time regarding the beast-like qualities of some of his neighbours. Most lovers of animals will find some interest in the study of lore of this

kind, much of which may still be gleaned in out-of-the-way places.¹

Fable, however, embodies only a very embryonic stage of poetic sympathy. We have still to look for the naturalist who will let us into the secrets of animal lives, tell us what they really are, and help us to translate their ideas and feelings in terms of our own. "We should go to the ornithologist with a new feeling," says Emerson, "if he could teach us what the social birds say, when they sit in the autumn council, talking together in the trees. The want of sympathy makes his record a dull dictionary. His result is a dead bird. The bird is not in its ounces and inches, but in its relations to nature; and the skin or skeleton you show me, is no more a heron, than a heap of ashes or a bottle of gases into which his body has been reduced, is Dante or Washington."

We have made some progress, certainly, since the day when Zoology was a study of ounces and inches; it is now a study of homologies and phylogenetic histories. But we must not therefore think we have attained everything that is to be desired. That accurate description of details of outward form which

¹ As a specimen of the humorous in fables of animal life, nothing better can be named than Ralston's translation from the Russian of Krilof's fables (Cassell: 1883, 3s. 6d.). The student in search of information regarding the place taken by various animals in mythology and fable should consult the English translation of *Animal Mythology*, by Prof. A. de Gubernatis (Trübner, 1872).

of old constituted the whole science of Zoology, was only a stepping-stone towards the attainment of the higher knowledge embodied in our modern ideas of development and evolution. These in their turn will serve as the firm foundation of a larger philosophy : a science which will find place for clear and sympathetic understanding of the manifold varying forms under which we recognise the mysterious unity called Life.

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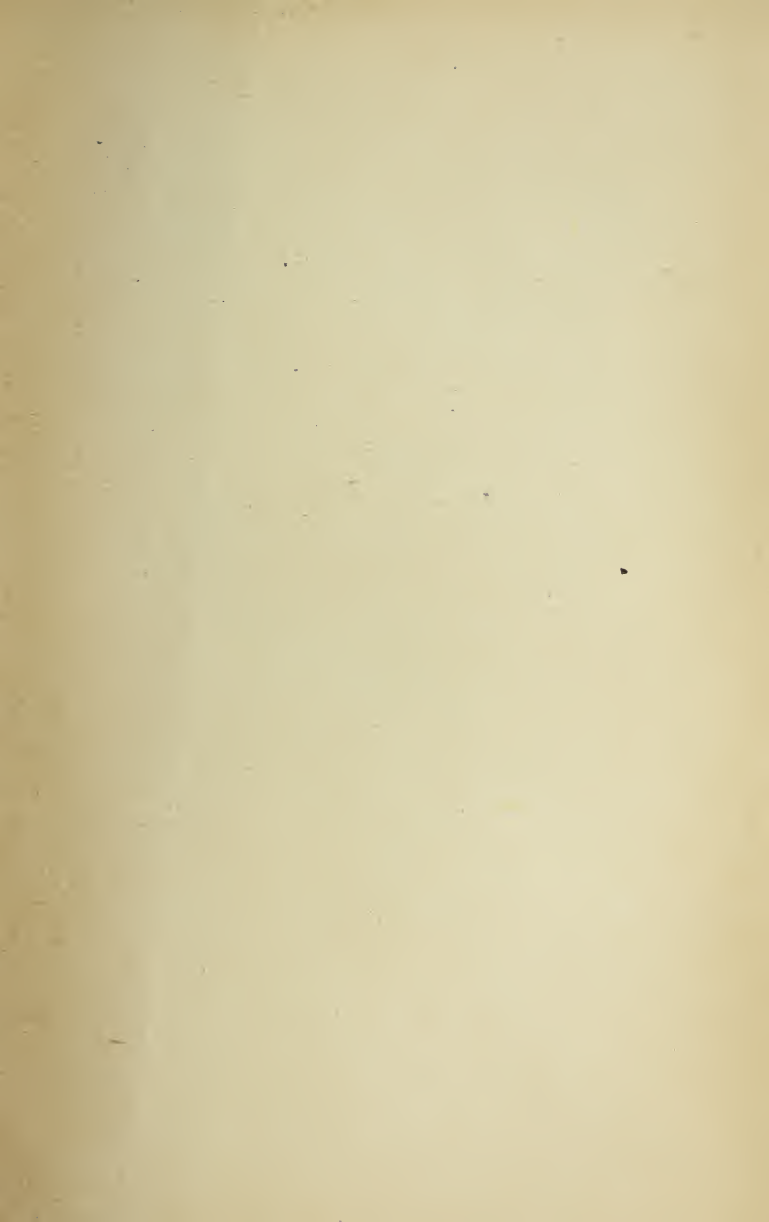
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